SCIENCE IN EVERYDAY LIFE

SOME OF NATURE'S GIANT FORCES

A. T. McDOUGALL, B.A., B.Sc.

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TO THE YOUNG READER

WHEN you have read through this book you will have learned something of the great part that science takes in the everyday life of this busy world of ours.

Make all the models you can and carry out the little experiments at the ends of the chapters. Most of the models can be made from the very simplest, commonest things which every boy can get for himself. If you are lucky enough to have a set of tools and some strip wood, you will be able to make your models with a much better finish than your less fortunate companions. A little paint or pastel often converts a model that looks rough into quite a nice looking article. If you can find a better way of working out the *idea* in a model, by all means do it in your own way, for you will thus become an inventor—a humble one perhaps at first, but yet an inventor.

It is surprising how much *real scientific knowledge* can be picked up in the way we have suggested to you. You will find that after a little practice in model-making, it will come easy to you, and things that appear difficult at first will soon become quite simple.

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ILLUSTRATIONS

SOME OF NATURE'S GIANT FORCES

CHAPTER I

The Force of Gravity

"Few of us know how much we must know,
in order to know how little we know."

THESE are the words of a very famous Frenchman and I am sure that as you grow older and wiser you will understand more and more the great truth which Rousseau has expressed so well.

It is surprising how little we really know about things going on around us day by day.

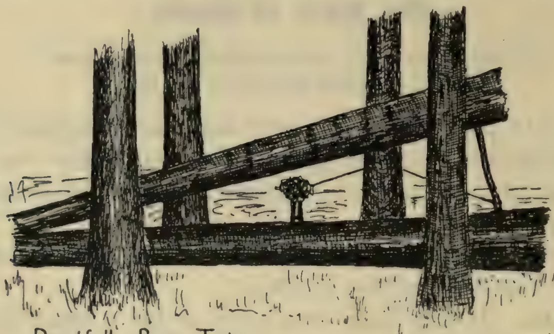
Weight. If you have ever tried to lift a small barrel, as the drayman does, you must have felt the pull exerted by the earth. In fact, the attempt to raise such a heavy object involves you in a "tug of war" with Mother Earth, and in the struggle you realize how hard she can pull at times.

As many others have done, you may have discovered that a more successful way of moving the barrel is to roll it. No doubt most of you have pushed or pulled a garden roller. Many of these small rollers are extremely heavy, yet they can be pulled or pushed by a few boys. But how many would be required to lift one bodily from the ground ?

This subject, however, will be considered more fully later on. At present it is sufficient for us to recognize that weight is exerted downwards. This property of

weight which all things possess, more or less, has been turned to useful purposes by man from very early times. Nowadays, we see it used in our streets when steam-rollers crush stones into the roads and in the fields when horses and men drag a roller over the ground after the seeds have been sown. Let us examine some further uses.

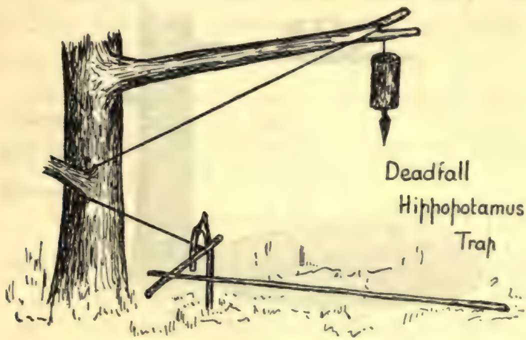
Deadfall Traps. In the great pine forests of North America the grizzly bear roams at his ease. He is a



Deadfall Bear Trap

very dangerous enemy for the hunters to attack with arrow or with gun. But he can be caught in a trap—a very simple one, although it takes a day or so to make it ready. Two pine trees must be felled and trimmed of their branches, so that they may rest lengthwise one on the other without a space between. Then the thick end of the top trunk is propped up about five feet, by means of one of the branches cut off. A cord is attached to the bottom of this prop, passed under a forked bough driven firmly into the ground or as arranged in the sketch above, and tied to the bait—usually some putrid salmon or a piece of deer's flesh propped up on a stick. The trap is so arranged that the bear can reach the bait only by putting his head between the tree trunks.

As soon as he pulls the bait, out comes the prop and down comes the tree trunk with a crash. As a tree trunk is very heavy, the bear is usually killed outright. In this way the cunning trapper puts the pull of the earth to use. Lighter traps of the same kind—deadfall traps



they are called—are put in the branches of trees to catch the smaller fur bearing animals that have their homes in the forest.

Livingstone tells us how the natives in Africa catch the hippopotamus by means of a very simple trap depending upon the pull of the earth. A heavy beam with a spear head—often poisoned—fixed in the end, is hung up over the path the hippopotamus takes to get to the river for a swim or a drink. Exactly under the beam is placed a long branch upon which the animal must tread as he marches down to the water. But this branch, as soon as it is touched, releases the cord holding up the spear, which comes down with all the weight of the beam behind it to drive it into the animal.

Pitfalls. Wolves abound in the wilds of Siberia and the natives use pitfalls to capture them. These are just holes dug in the ground, often under the overhanging

branch of a tree. The holes are concealed with twigs which will bear only a small weight.

On the branch above is fastened up, just out of reach, a piece of goat's flesh or some other tempting morsel. Along comes the wolf, scents the bait, jumps at it and

Siberian Pitfall Trap (uncovered)

misses. Down he comes with a thud upon the roof of the pitfall which will not bear his weight, and the wolf falls in. But the natives have thoughtfully put a few spears—point upward—in the pit, and the wolf waits till the trappers come to help him out. If you have read the *Children of the New Forest* you may remember how Humphrey took cattle in his pitfall.

Men have been trapped in this way too! You must have heard of the fierce wars between King Edward I and the Scots led by Wallace. Here is an interesting passage about one of the encounters. "Wallace marched into Cumberland. . . For the first time he was going to pit his soldiership against the greatest general in Christendom. His aim was to draw the King towards the Scottish lines where he had dug deep pits and covering them with twigs and grass, had left them as traps for the Southern cavalry. . . . . Wallace stood unmoved. Not a bow was drawn

until the impetuous English squadron, in full charge towards the Scottish flank, fell into the pits. Then the highland archers launched their arrows. . . Terrific was the havoc."[1]

Portcullis. In speaking of these bygone days we remember, too, how barons used to close their castle gates against their enemies. Perhaps you have learned these lines from Sir Walter Scott's "Marmion" —

> "Up drawbridge groom! What warder ho!
> Let the portcullis fall."
> Lord Marmion turned—well was his need—
> And dashed the rowels in his steed.
> . . . .
> The bars descending razed his plume."

The portcullis, of which there are still a few examples to be seen in this country, was a great metal covered gate which, instead of swinging on hinges as our gates do, dropped from above under its own weight. It had little need of bolts or bars to fix it for when once its weight had brought it down it required powerful machinery to lift it again!

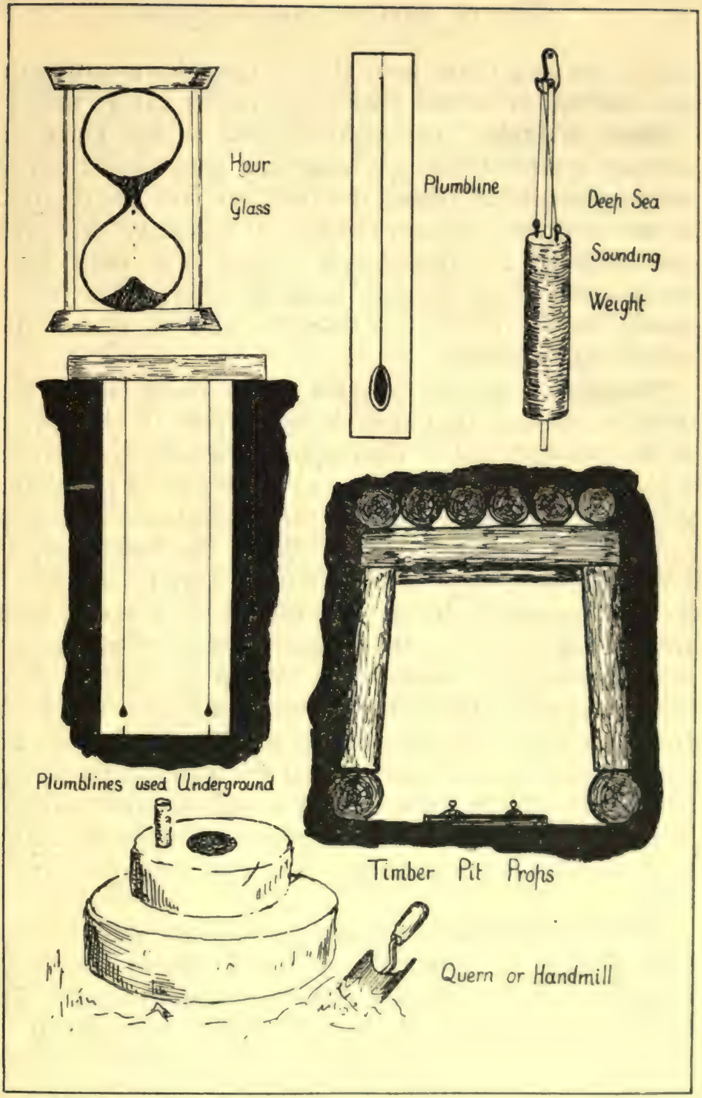
Hour Glass. But those days have passed away. The years have been measured out one by one by Father Time. Have you ever seen a picture of him carrying his scythe and his hour glass? Perhaps you can find out why he carries this scythe. He has an hour glass because it measures time. In fact, it is one of the oldest methods known for measuring time. It consists of two pear-shaped glass bulbs joined neck to neck, with sufficient sand in one of the bulbs to take just one hour to trickle down to the other. They were not of much real help for telling how the hours were going by, for they would frequently be forgotten at the end of the hour, and if

[1] Jane Porter's *Scottish Chiefs*.

they were not turned at the proper moment the "clock would be slow." The Romans were great orators and often said much, as speakers do to-day, that was uninteresting. They had an "hour glass" that ran only 5 minutes, just about as long as our egg-timers do nowadays. That was used as a gag to stop one orator and give another a chance. In the middle ages, too, sand glasses were used to measure out the length of sermons. In the West of England there are still a few pulpits with an "hour glass" at the side.

A story goes, that during the wars of the seventeenth century, a town was to be taken by assault at midnight. The general gave instructions to one of his captains to attack at the east end of the town, while he himself made the main attack at the west end. The general turned the hour glass and told the captain to lead his men out when the sand had run through.

The captain got his men ready and then dozed, looking frequently at the glass to see if all the sand had run out. Suddenly he was awakened by the guns. He knew the attack had begun and that he was too late. He looked at the hour glass. The sand had stopped running! He touched it and it went on again. The attack failed. The general on the way back called upon the captain to explain. He told the general what had happened—but was not believed. The general called a sergeant and four men. Then he took the hour glass, turned it, and ordered the sergeant to shoot the captain when the sand had run through. The sand trickled down until suddenly it stopped as it had done before! The captain told the sergeant to ask the general to come and see it for himself. Needless to say, when the general arrived the captain was reinstated. The grains of sand had been carelessly selected and two or three big grains accidentally


Hour Glass
Plumbline
Deep Sea Sounding Weight
Plumblines used Underground
Timber Pit Props
Quern or Handmill

met in the neck of the hour glass in their downward path. You see that even hour glasses, like clocks, can go wrong!

Clock Weights. Although the pull of the earth on the tiny grains of sand has long since gone almost out of use as a means of telling the time, we still use the pull of the earth to drive our clocks. If you have ever seen the inside of a "grandfather" clock, you must have noticed the great weights hanging there. The earth slowly draws down these weights and so causes the wheels to go round.

Plumbline. As the weights hang there, so slowly do they descend, that they do not appear to be moving at all; but they are. Each appears to hang as steady as a plumbline. Do you happen to know what a plumbline is? It is a piece of lead—or other substance—hanging at the end of a single string. When the builder erects a wall, he uses his plumbline to make sure he is keeping it quite upright. He fixes it usually in a board with straight edges, so that the "bob" or lump of lead hangs in an opening near the bottom. When the straight-edge is quite upright, the string covers a line, or a notch on the lower end of the board. If, when he is at work, he puts the edge of the board against the wall and the string hangs correctly, he knows that the wall is quite upright. The string is straightened by the pull of the earth on the lead, and hangs vertically when the weight is quite still.

Deep Sea Sounding. Weights fixed to the end of a line have been put to other uses, too. No doubt you have heard of the telegraph cables that run under the sea. To find out how many miles of cable must be made, it is necessary to know the ups and downs of the floor of the ocean—for it is anything but level. It has its hills and its valleys just as the land has, but they are all under

water, and to find out about them the ocean has to be sounded. Sounding is a very slow process. Weights of iron, about half a hundredweight each, are attached to a wire about as thick as a pianoforte wire and lowered over the ship's side. The weight carries the wire to the bottom. The engines keep the ship from moving—for the sounding must always be "straight down." As soon as the weight touches the bottom it falls off and then the wire let out is measured as it is wound in again. It takes about half an hour to measure a depth of two miles, and as the whole course the cable is to cover has to be carefully sounded, this work may take many months to complete.

Tunnelling. Another interesting use to which the plumbline is put is in mining. Often two shafts have to be sunk, perhaps a mile apart, and the miners wish to join them underground by a tunnel. How can this be done, for when the men are half a mile down in the ground they are unable to look across to the other shaft to see that they are going directly towards it. A slight deviation at the beginning causes a big error at the end so that great care has to be exercised. Yet they can tunnel from each shaft and be pretty sure to meet half-way, although they work half a mile underground all the time.

Across the top of the shaft they place a beam whose centre line is sighted to point exactly to the top of the other shaft. Then from this centre line two plumblines are lowered into the shaft till they reach within an inch or two of the bottom. When they are quite steady, a peg is driven into the ground beneath each. The line joining these pegs gives the exact direction in which the miners wish to go. During the Great War, tunnelling was directed many times in this simple way.

Pit Props. When the miner is tunnelling underground there is one thing he must carefully do as he moves forward. He must prop up the roof and sides of the tunnel to prevent them from falling in and crushing him, for the earth draws everything towards its centre. For this purpose many thousands of pit props are used each year. During the Great War we were much troubled, at first, because the Germans sunk the ships bringing our pit props from Scandinavia. Finally, we had to cut down our own forests to provide props, for it was absolutely necessary for the mining of coal and iron and lead to be maintained. But these props are of wood and will not last for ever. The moisture in the ground gradually rots them away. Then the pull of the earth gets the mastery, and down sinks the ground leaving great holes on the surface where before had been level fields. Sometimes the mines run under towns; then when the ground collapses houses break to pieces or disappear. Lives have been lost in this way in the mining districts, for often the collapse takes place without warning. Some years ago the ground fell into a mine running under the Furness Railway. An engine was standing on the line. Its weight snapped the rails when the ground fell away, and the engine fell into the hole caused by the subsidence, and was completely lost.

Pillars. Some of the noblest buildings in our own and other lands show massive or slender pillars, beautifully shaped, used to counteract the pull of the earth upon the structures above them. Pillars have formed one of the leading features in the great buildings of Hindoos, Egyptians, Greeks, and Romans. In our own buildings we still largely use the lighter pillars of the Greeks and Romans. Egyptian pillars are not suitable to our style of building.

Speaking of the Egyptians, calls to mind the plagues which were inflicted upon them. The last plague was the death of the "first born," from that of "Pharaoh that sitteth upon the throne even unto the first born of the maid that is behind the mill"—from King to slave.

Mills. The mill was a much simpler affair than the great buildings to which we give the name nowadays. It was just a stone weight resting upon another stone, in such a way that it could be turned round and round by hand. The corn was put into a hole in the upper stone and trickled down to be crushed between the upper and the lower millstones. The millstone was such an important thing in the lives of the people that Moses forbade its being taken as a pledge as it was considered "a man's life." Samson, as a prisoner, ground corn in such a mill. When the Romans came here they found the "quern," or handmill, in use among the Ancient Britons. With all our advanced knowledge just the same old idea is adapted in our great up-to-date corn mills—one heavy stone turning upon another and crushing the corn between.

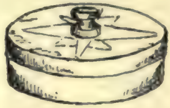
Weights. Weight, the steady pull of the earth, is always present. Never a day passes without our calling it into use in some way. Buying by weight is much fairer, all things considered, than buying by measure. But it takes much more time to weigh than to measure. In order that we may get the weight we pay for, all weights are inspected by many "Inspectors of Weights and Measures." Last year alone the London County Council authorities tested over a quarter of a million separate weights, making some 84,000 visits to see that the weights were exactly what they should be. Only about 130 cases of fraud were found among the hundreds of thousands of tradesmen in London.

Have you ever heard of the wise men of Gotham? They lived in the reign of King John, so we are told. One of them went riding to market. He put two great sacks of corn on the donkey's back and then got on himself. After a while he thought the donkey was a bit tired and decided to relieve it of some of the weight. He hung the sacks one on either of his own shoulders and then rode on as before. What do you think of his kindness?

Gravity. Now you have learned from what has been said that the earth is constantly pulling all things towards its centre. The something with which it does the pulling is called a "force." The force with which the earth pulls is called the "Force of Gravity." We cannot say what it really is, but we do know what it does. Some little time ago an American boy had to write at an examination what he knew about Sir Isaac Newton. This is what he wrote: "Ike Newton was the slacker who went to sleep under an apple tree. A ripe one fell on his face. To account for the mess and prevent his wife laughing at him, he invented gravity."

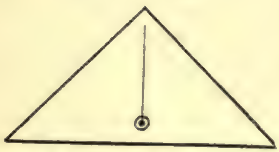
I hope *you* will never accuse Sir Isaac Newton of inventing gravity—something which has existed since the world began. Sir Isaac Newton was one of the greatest thinkers the world has ever known. During the year of the Great Plague of London, 1665, he stayed at his farm at Grantham. As he was reading one day under an apple tree, an apple fell and struck him sharply on the head. When he observed the smallness of the apple, he was surprised at the force of the blow. This led him to consider the matter carefully, and after much thought he taught us all that we now know about gravitation or the pull of the earth.

(1) Thimble Mouse Trap

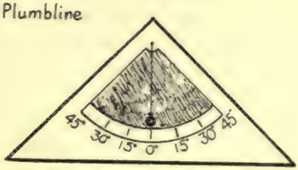


(2) Paper Weight

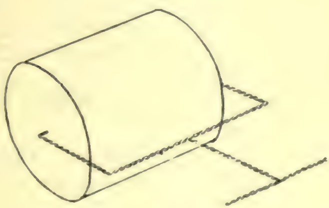
(3) Plumbline



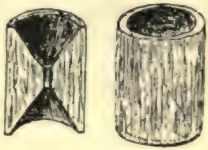
(4) Plumbline for horizontal



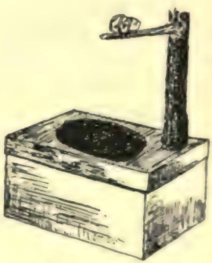
(5) Clinometer



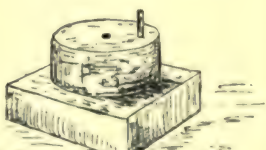
(6) Garden Roller



(7) Hour Glass



(8) Pitfall Trap



(9) Quern

SOMETHING TO DO

1. **Thimble Mouse Trap.** A basin supported by a thimble half full of oatmeal. A slight touch causes the thimble to slip and the basin falls, enclosing the mouse.

2. **Paper Weight.** A box, loaded with sand. The handle is the top of a clothes peg fixed by a small screw in the underside of the lid or a shanked button with the shank passed through a hole in the lid and held firmly by a wedge. Cover the whole with paper and design and colour according to taste.

3. **Plumbline.** A pegtop bowl inverted and a string attached by a plug of wood. A smaller model (as in sketch) may be made from some card, cotton, and a button.

4. **Plumbline for Horizontal.** Take a cardboard square, cut diagonally into half and use one half. Make a plumbline from some cotton and a button, fix to the card; and cut a hole to accommodate the button.

5. **Clinometer.** Mark out on stout cardboard and cut away the shaded part. Make the plumbline as in (4).

6. **Garden Roller.** A circular tin with a lid, each end pierced in the centre. Wire is passed through these, and bent and twisted to form the handle.

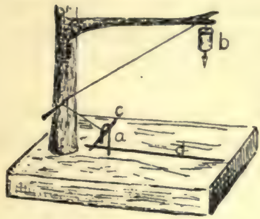
7. **Hour Glass.** A cork and two bottles, one fitting each end of the cork. Burn a hole down the centre of the cork with a hot knitting needle, and hollow out the ends. Place sifted sand into one bottle, fit the cork and place the second bottle neck down over the upper part. Invert the whole and note the time taken for the sand to run through.

8. **Pitfall Trap.** Cardboard box with a hole cut in the lid. Glue or nail a twig into position, and cover the hole with grass or hay.

9. **Quern.** Cotton reel working on a nail fixed in a piece of wood.

The model, turned on its side so that the reel lies horizontally, and fixed to a block for support, may be used to drive a potter's wheel, a circular saw or grindstone.

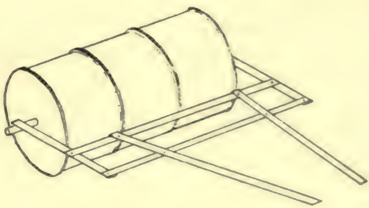
10. **Deadfall Bear Trap.** Fix four stout twigs to the baseboard by screws from beneath. Arrange the trap as on page 2, propping the upper twig with a thinner one connected to the bait with cotton as shown. Arrange other twigs around the bait so that it can be reached only from one side.



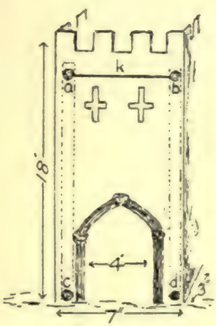
(11) Deadfall Hippopotamus Trap

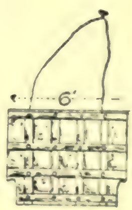
(13) Pigeon Trap

(12) Deep Sea Sounding Weight



(14) Clod Crusher





(15) Portcullis

11. **Deadfall Hippopotamus Trap.** Screw the twig to a baseboard from beneath. (*a*) Bent nail or wire ; (*b*) cotton reel with spike attached ; (*c*) smooth twig passing through a loop at the end of the cotton ; (*d*) long twig resting on (*c*) to spring the trap when trodden on.

12. **Deep Sea Sounding Weight.** A penholder with a slot cut at one end to take the tin hook. Drill or burn with a needle a hole across the slot for a pin to hold the hook. Two or three reels, and a loop of cotton arranged as shown complete the model.

13. **Pigeon Trap.** Cotton reel and three knitting needles. Fix two firmly in the reel and use the third needle as an axle. The pigeon pushes against the door which lifts and allows him to enter. The door then falls to against the ledge at the bottom. As the door opens inwards only, the bird is captured.

14. **Clod Crusher.** Three reels arranged on penholder as axle, and a frame and shafts fixed as in sketch.

15. **Portcullis.** Dimensions as shown (or half-size). Card 18 in. by 13 in., bent twice to form the walls ; four pieces of cork about $\frac{1}{8}$ in. thick, *a, b, c, d,* are glued at back of front wall as shown ; a knitting needle passes from cork *a* to *b* ; two strips of card about 1 in. wide are fixed from *a* to *c* and from *b* to *d* to act as guides for the portcullis (cotton or string might be used). The portcullis is drawn as shown and crayoned. Take 2 ft. of cotton and fix to the top of the portcullis as shown. Bend the portcullis to put it behind the runners ; pass the cotton over the knitting needle and fix a button at the middle to prevent it falling out of position when the portcullis drops.

CHAPTER II

Inertia

AWAY in the far western states of America, in what has been called the "Garden of the Gods," are to be seen some of the most wonderful objects on the face of the earth. They are called the "Lone Rocks." Each pillar is made up of a slender column capped by a great block of stone. They have stood so for ages past, and will remain standing for ages to come—until indeed something happens to upset them. An earthquake may dislodge the cappings, the supporting pillars may perhaps crumble away, but until something happens to interfere with their rest, there they will stand.

Inertia of Rest. No lifeless substance has yet been known to move on its own account—it requires some disturbing cause to shift it. Sir Isaac Newton has put this fact into words for us: Anything at rest will remain at rest until some force makes it move. This property of all material—that it is unable to move of itself—is called "inertia."

If you have not read the *Talisman* by Sir Walter Scott there is a treat in store for you. It is the story of the doings of Richard I in Palestine. On one occasion he was the guest of his great enemy Saladin, who much admired Richard's great sword.

"Had I not," said Saladin, "seen this brand flaming in the forefront of battle, I had scarce believed that human arm could wield it. Might I request to see thee strike one blow with it in peace, and in pure trial of strength?"

"Willingly, Noble Saladin," answered Richard, and

looking around for something whereon to exercise his strength he saw a steel mace, with a handle of the same metal about an inch and a half in diameter. He placed the mace on a block of wood, with the handle projecting. The glittering broadsword wielded by both his hands, rose aloft to the King's left shoulder, circled round his head and descended with the sway of some mighty engine, and the bar rolled on the ground in two pieces, cut as a woodman would sever a sapling with a hedging bill.

"By the beard of the Prophet, a most wonderful blow!" said Saladin. You see the inertia of the bar which was at rest had allowed the quickly moving sword to shear clean through it before it began to move itself under the blow. Saladin then performed a similar act about which you can read for yourself.

If you look carefully at the reaper as he plies his scythe, you will see the blade cut through the grass as he mows. But the grass drops where it stood—it is the scythe that goes on. Inertia keeps the grass where it stood. Richard the First's action, when he cut through the mace, was of the same nature as that of the reaper.

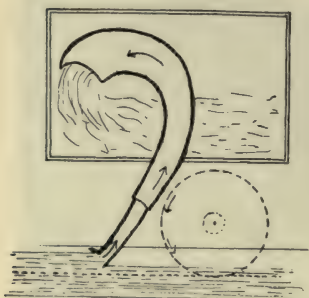
Locomotive Tank Feed. In these days of rapid travelling a very useful application of inertia is found in the arrangement which enables an express train to take up water for its engine when travelling at 60 miles an hour or more. Between the rails is a long narrow trough of water and from the tender of the engine is a bent pipe which dips two inches into the water in the trough when lowered by the driver. The water is still and inert. The pipe is carried quickly through the trough. The inertia of the water skimmed off by the pipe and the shape of the pipe together cause the water to slide up into the tank.

Whilst travelling in search of the sources of the Nile,

By courtesy of the *Great Western Railway Co.*

AN ENGINE TAKING UP WATER, WHILE TRAVELLING 60 MILES AN HOUR

Bruce, the explorer, spent days at a time in different African villages. On one occasion he wished to impress a chief with the power of his gun and to show the chief that the hide shields of his tribesmen were quite useless against it. The chief disbelieved what Bruce said, upholding the strength of his shields. The matter was put to the test. The chief put up three of his best shields, one behind the other for Bruce to spoil—if he could.



A Locomotive Tank Feed

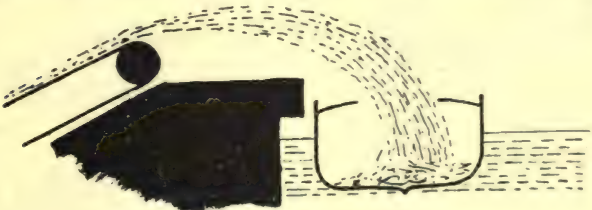
How Bruce's candle spoiled three shields

Bruce to the chief's astonishment did not load his gun with a bullet, but with a candle! The chief laughed. Bruce fired at the shields and the chief no longer laughed, for three of his best shields were spoiled. Each had a large hole in it. The candle travelled at such a great speed that it carried with it a piece of each shield, and the inertia of the shields caused them to remain just where they stood.

It is the same inertia that enables a bullet to go through a glass window making only a small hole instead of shattering the glass. During the German air raids upon London many glass houses had holes perforated in the glass by small pieces of shrapnel falling from a great height, but the whole pane was not broken.

You have seen something of the same kind if you have watched the scavengers shovelling up the heaps of dirt at the side of the road. They make no attempt whatever to keep the dirt still, but push the shovel under it as quickly as possible. The inertia of the dirt makes it remain motionless until the shovel is well under it when the dirt takes up the motion of the shovel and goes with it.

Inertia of Motion. Now, you might think, if you haven't seen him at work, that the scavenger carefully puts the shovel over the side of the cart and tips the dirt into it. Instead of this, he swings the shovel of dirt in the direction he wants the dirt to go, and then stops the shovel. The



A Grain Elevator

dirt goes on and without any further help falls into the cart! What is called "inertia of motion" prevented the dirt from stopping in the shovel when the shovel ceased to move. We have seen that things at rest keep at rest till forced to move. We now learn that things moving keep moving till made to stop. But you may ask: "Why did not the dirt keep on moving for ever and ever?" There are two good reasons. One that it was resisted by the air; the other that it was drawn down by the pull of the earth. These two forces counteracted the motion of the dirt and made it fall into the cart.

Grain Elevator. This inertia of motion has been turned to good account in many other ways. For years

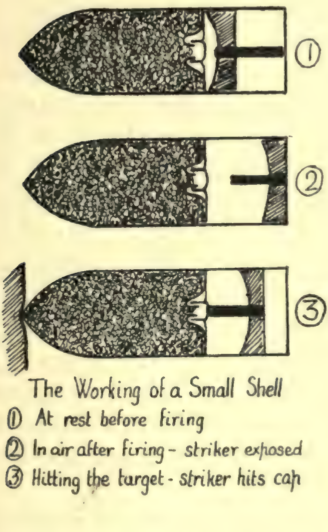
it was used at grain importing docks to lift grain from a lower to a higher level in the grain elevator. The grain was delivered on to a fast moving band of cloth and rubber passing over rollers. The grain took up the speed of the band and when suddenly the band passed round the roller, and dipped down from under the grain, the grain flew on with the speed of the band, and its inertia of motion carried it quite a distance before it dropped. Vessels can be loaded with grain in the same way.

Shell Mechanism. This inability to start or to stop moving has played a very important part in the working of small shells. Some shells burst only when they strike an object in their path. Let me explain why this is. In the front part of the shell is the exploding charge which goes off when the cap in the shell is struck. At the back of the shell is the striker, embedded in a piece of lead so that it cannot touch the cap. When the shell is fired from the gun the inertia of the lead keeps it still while the shell goes on. This makes the lead move down to the other end of the striker. Now there is nothing to keep the striker from getting at the cap. When the shell strikes an object its motion is suddenly stayed, but the lead with the striker goes on, on account of its inertia of motion, and the exposed striker is driven on to the cap. So you see inertia is used twice over in the exploding of a small shell.

Just the same kind of thing happens to a passenger standing in a train. When the train starts, his feet being on the floor are part, as it were, of the carriage and go on with the carriage, but his head is inert and tends to stop behind. So unless he holds some part of the carriage he is liable to fall with his head away from the engine.

When the train stops just the reverse takes place. His feet stop with the floor but his head tends to go on, and he is likely to fall with his head towards the engine this time.

Pendulum. One of the commonest cases in which inertia is turned to account is the pendulum. It consists of a weight at the end of a light rod or a string. To start



The Working of a Small Shell
① At rest before firing
② In air after firing - striker exposed
③ Hitting the target - striker hits cap

Pendulum Bear Trap

it we move the " bob " or weight a little to one side of its vertical position, thus raising the weight a little at the same time. Then we let it go. It swings down to its position of rest—but cannot stop there. Its inertia of motion carries it on, and it rises a little on the opposite side of its vertical position, till the gentle pulling of the earth stops it rising. Then it drops back again and, as you know, repeats these movements. Quite a large

number of our clocks depend upon the pendulum for their time keeping. But there are two other uses to which the pendulum is put, and of which perhaps you have never heard.

Bear Trap. In several parts of Europe and Asia the brown bear is found. He is caught by means of a pendulum! The hunter knows the bear's weakness for honey and sets to work using this knowledge. He selects a tree with two branches one above the other, and about six to eight feet apart. The bottom branch is well above the ground. On it, about twelve feet from the trunk, he places some honey, a bait no brown bear can resist. A few feet in front of the honey he hangs a pendulum—a heavy rock at the end of a rope—suspended from the branch above. The trap is ready. Bruin scents the honey and scrambles up the tree to get it. He finds his path blocked with a piece of rock. He pats it out of his path. It comes back and pats him. This annoys him and he hits it harder. It comes back and hits *him* with increased force. More annoyed still, he hits it as hard as he can. It returns the compliment and gives him a blow equally hard, so hard indeed that it knocks him off his perch. His fall breaks his neck or his back or his legs. Then the hunter comes along and he and the bear go home together!

A more recent use of the pendulum has been for breaking down the half-ruined houses in the battle area in France. A weight on the end of a rope is set swinging from the end of a long beam, when it batters down the crumbling walls much quicker than men could do, and with very little danger to the workmen.

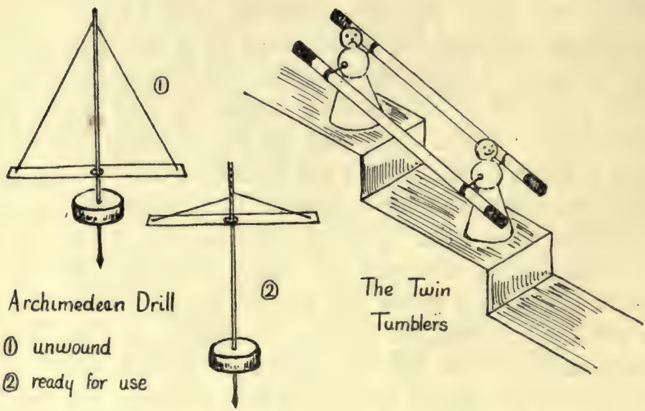
Backward and forward motion due to inertia is seen in the rocking chair, the rocking horse, baby's cradle and the swing as well as in the pendulum.

Archimedean Drill. As you learn more and more science you will hear more and more of Archimedes. He lived at Syracuse in Sicily where he was killed by a Roman soldier while he was studying a drawing he had made in the sand—for there was no paper then to draw on. But he has left behind discoveries and inventions that have astonished the world. One of his simplest inventions, the "Archimedean drill," we can study now, as its working depends upon inertia. It is a long round stick with a drill at one end. A little above the drill a heavy wheel is fitted on the stick—a wheel such as a boy has on his roller skates. Above the wheel is the driving handle—a thin piece of wood working easily up and down the round stick. From each end of the driving handle a string is fixed to the top of the round stick. To set the drill to work we hold the handle still and wind the strings around the long stick by gently turning it. As we do so the handle rises towards the top. Standing the drill upright we lightly press the handle down. This makes the stick spin, but the inertia of motion of the heavy wheel carries it on till the string is wound round the stick again—but in the opposite way. Pressing the handle down again we set the drill spinning in the opposite direction, and so we go on spinning the wheel—and the drill—backwards and forwards. The weight of the wheel also presses the drill into the object. Watchmakers and clockmakers use this kind of drill. So do menders of broken china, for it is useful for any light work.

The Bolas. A very strange weapon, the bolas, is used by the South American Indians for hunting. It is made in several forms by different tribes. The very simplest form is a stone fastened to a long rope. "This end (the stone) is swung round the mounted hunter's head in a circle, and then cast with precision towards the animals

he wishes to strike, in such a way as to make the stone twist many times round the neck or legs of the fugitives, and so arresting them in full career."[1] The inertia of the moving stone works the bolas.

The Tumblers. Some years ago, Paris, the home of clever scientific toys, was much amused at the "tumblers." They were two little figures whose loosely fitting wire arms were joined firmly to two light tubes, one on each



side of the figures. Each tube contained a little mercury. Stairs were provided. The tumblers were placed on the top stairs. A light push of the upper figure made it touch the second step. The mercury rushed to the lower end of the tubes and in doing so swung up the other figure whose inertia of motion carried it down to the third step when once more the mercury ran down, and so continued the movements of the figures.

Let us finish this section on inertia with the story of Brady's Leap, from Cassell's *World of Adventure.* Brady

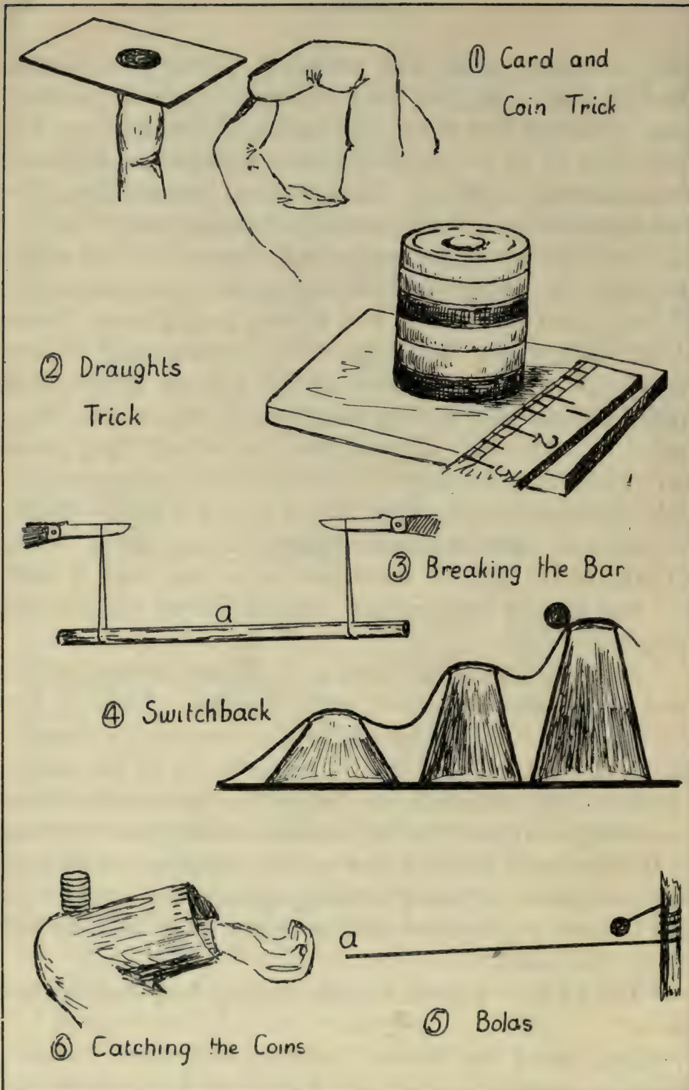
[1] *Swiss Family Robinson.*

was a hunter who had inflicted many losses upon the Red men. At last they thought they had cornered him. " Brady saw their stratagem. He must cross the river, but to do so under the bullets of his enemies was almost certain death. . . They wanted to take him alive and torture him. Brady knew well enough why they did not fire. He made for a spot well known to him where the river is compressed between two precipices, but 22 feet apart at the top and a deep and gloomy chasm at the foot where the river boiled impetuously 50 feet down. A short way above, the stream is 50 yards wide at least, and widens immediately below the rocky pass . . . . . This was the one spot of all others they would have wished him to run for. With his back to the precipice they would take him alive like a rat in a trap. Brady did not care to measure the chasm with his eye. Within 20 yds. of the top he shortened his stride, took a swift run and sprang forward into the air above the swirling waters.

" The leap was, as we have said, 22 feet across and this man was somewhat spent with running. Now 22 feet is a big jump for a modern athlete in the pink of training. Brady did not quite strike the opposite lip of the chasm. But it so happened that just below the lip a narrow ledge protruded, and into this the hunted man dropped, catching at the shrubs as he fell to prevent his toppling backwards. For a moment he hung panting against the wall of the cliff ; then seizing the shrubs again he pulled himself up to the crest . . . . . .

" The Indians looked at that mighty leap and turned back."

Brady owed his life to " inertia of motion " which, when he made his final spurt, carried him across the chasm.


① Card and Coin Trick
② Draughts Trick
③ Breaking the Bar
a
④ Switchback
a
⑤ Bolas
⑥ Catching the Coins

SOMETHING TO DO.

1. **Card and Coin Trick.** A heavy coin and a thin, smooth card arranged as in the illustration. Flick away the card, and the coin remains.

2. **Draughts Trick.** Pile of draughts or coins. Remove the black draughts by a swift sweep of a flat ruler.

3. **Breaking the Bar.** Two boys hold knives as shown. (They should have their backs to the striker—and shut their eyes or they may wince when they see the poker moving.) Use string or paper loops. The stick may be a dry branch of a tree, or of the kind used to roll tracing paper or maps on. Strike as swiftly as possible with a heavy poker, at *a*. The stick should break but the loops remain, uncut.

4. **Switchback.** Three books, strip of paper, and anything that rolls ; e.g. marble, pencil, nut.

5. **Bolas.** Three or four feet of twine, with a heavy button fastened at the end. Whirl in a horizontal circle, strike the upright with the *string* about 1 ft. from the button.

6. **Catching the Coins.** Arrange as shown. Drop the elbow quickly, and catch the coins before they start moving.

7. **Cap Banger.** An old barrel key, and a French nail with the point ground flat, 1 yd. of string, arranged as shown. A paraffin match-head or cap is pushed to the bottom of the barrel and the nail pushed in. Swing the head of the nail against a wall. The inertia of the key explodes the cap.

8. **Tee-to-Tum.** Match stick fixed in a slice of cork. Spin between thumb and finger.

9. **Numbered Tee-to-Tum.** Thin stick and cork slice cut to the shape of a hexagon, and numbered 1 to 6.

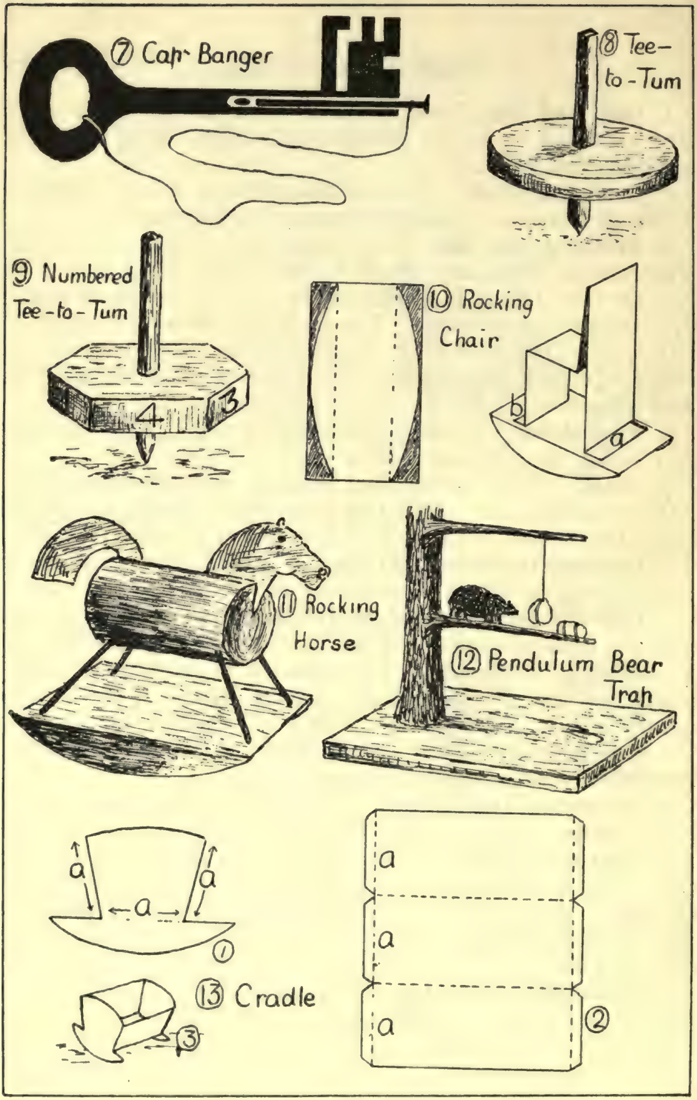
10. **Rocking Chair.** Cut rocker from a post card, and the chair from a strip of paper, a little narrower than the rocker platform. Fold as shown, and gum *a* and *b* to platform.

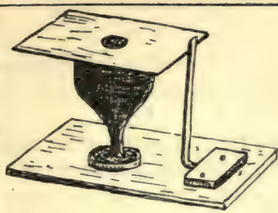
11. **Rocking Horse.** Rocking horse from cork and matches or large pins.

12. **Pendulum Bear Trap.** Twig as shown, screwed to base-board from below. Make a plasticine bear.

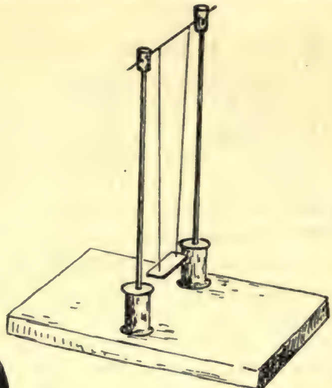
13. **Cradle.** (1) Two end pieces ; (2) sides and bottom. "*a*" is the same length in (1) and (2). Bend (2) at dotted lines, and fix up as in (3).

14. **Cup and Coin.** Fix a piece of crinoline steel to a base

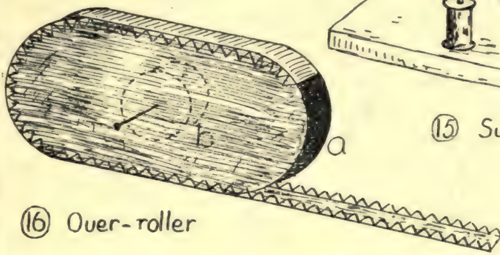

⑦ Cap Banger
⑧ Tee-to-Tum
⑨ Numbered Tee-to-Tum
4
3
⑩ Rocking Chair
b
a
⑪ Rocking Horse
⑫ Pendulum Bear Trap
a
a
a
①
⑬ Cradle
③
a
a
a
②



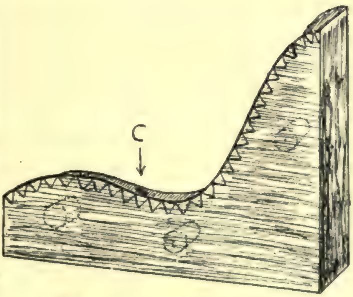
(14) Cup and Coin



(15) Swing

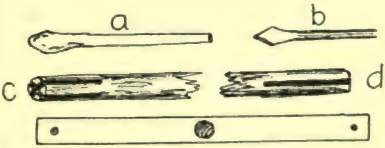


(16) Over-roller



(17) Switchback

(19) Twin Tumblers



(18) Archimedean Drill

as shown. Place cup, card and coin in position. Pull back and release the crinoline. The card is swept away and the coin falls into the cup.

15. **Swing.** Two cotton reels fixed to base with glue, nails, or screws. Two bamboo flower sticks with corks fixed to the tops and a knitting needle pushed through to form a crossbar. Make a card seat with cotton supports.

16. "**Over-roller.**" Two card sides with semicircular ends. Pin card sides in position to the cork *b*. Put on strip of gummed paper, leaving opening at *a*. When fixed, take out pin, shake out the cork—put in 8 or 10 lead shot and close *a*. Stand it on an incline on one of its round ends, and it will roll over in spite of its oblong shape.

17. **Switchback.** Two shaped pieces of stiff card; three corks as distance pieces; strip of gummed paper cut at edges as shown. Fix over the curved sides to give a track for the marble, cutting a hole at *c* for the marble to jump. Cover each side with gummed paper, giving $\frac{1}{4}$-in. rim to track.

18. **Archimedean Drill.** Tap a red-hot knitting needle to shape *a* and grind on stone to shape *b*. Cut the drill with a file or stone, giving 2 in. of stem. Heat it again, and drop it into cold water. The drill stick is 12 in. long, with a slot at *c* for drill, and at *d* for string. Fit up as on page 26.

19. **Twin Tumblers.** Two cork tumblers, shaped and hollowed to produce lightness; two straws—or thin glass tubes. Close one end of each tube with sealing wax, put in a little mercury, or fine lead shot, and close the other end. Put a light wire through the armholes and fix to straws as shown. The amount of tube below the wire of lower figure is less than the distance from shoulder to feet. Make the "stairs" of match boxes.

CHAPTER III

Porosity and Capillarity

Molecules. Those who have devoted much of their time to thinking upon the things round about us, tell us that all these things are made up of very tiny particles —particles so small as to be quite invisible even under the most powerful microscope. These very tiny pieces are called "molecules." We may, for our purpose, think of these tiny particles as tiny spheres. Now if we were to take a few glass jars and put into one of them nuts, into a second one peas, and into a third one mustard seed, and then tap the jars so as to make the contents get as closely together as possible, we should soon understand that, make the seeds go as closely together as we can, there are still spaces—tiny perhaps—between the seeds.

Pores. In this way all things around us are built up. There are spaces called pores between the molecules whether the substance be a solid, a liquid or a gas.

Although pores may be far too small to be seen, it is easy for us to show they are there. If we place a piece of white chalk in a saucer of red ink for a moment or two, and then take out the chalk and break it across, we should see that the ink has found its way through the pores to the interior of the chalk. All substances then, without exception, are porous, but the pores are not equal in size in all.

There are many things, however, which at first sight we might feel inclined to say had no pores. Who would care to assert that lead was porous? Water is brought into almost every home in lead pipes, yet the water does not soak through the lead. Nevertheless lead is porous.

Sir Francis Bacon, who, as a boy, was Queen Elizabeth's "Little Lord Keeper," was a thinker far in advance of his time. He made a hollow leaden ball, filled it with water, and sealed the opening carefully. Then he hammered the lead ball and found that the water came out all over the surface like dew drops. The water had been squeezed through the pores of the lead. The lead then was porous! Yet we often line tanks for water storage with lead. It is quite plain that water particles cannot easily make their way through the inter-spaces of the lead. Some scientists, who lived at Florence in Italy, did much the same thing about twenty years later with a hollow ball of gold, and found gold porous. Yet golden goblets have been in use in king's palaces from the dawn of history.

Impervious Substances. Substances that are porous but which do not let water pass through easily are often spoken of as "impervious." India-rubber is used for innumerable purposes nowadays, yet at the beginning of the eighteenth century it was brought from South America as a great curiosity. No one could tell what it was till in 1736 a Frenchman named La Condamine, while travelling through the unexplored forests of the Amazon Valley, discovered that it was produced by a large tree growing wild on the banks of the rivers. When rubber had been in use in this country for a time, a man named MacIntosh thought it would be a very good idea to make clothing waterproof. He invented a plan by which the pores in the cloth could be so blocked up by india-rubber that the cloth became impervious to moisture. We call our waterproof coats "mackintoshes" after him.

Another substance, used long before rubber was discovered, for making cloth waterproof is tar. There is

quite a large but scattered industry in most civilized countries for the making of " tarpaulins."

Think of the many railway trucks that are open at the top and have to carry goods in all weather, and you will realize how necessary some waterproof material is to keep the goods dry. Farmers, too, use tarpaulins to keep their hay dry ; on ships tarpaulins are used to cover the hatches in rough weather, and many delivery vans have tarpaulin covers. Tarpaulin is a coarse sacklike material treated with tar to make it impervious to wet.

Recently we have found a way of treating both cotton and silk fabrics with oil and making them in this way impervious to water, or, as we wrongly say, non-porous. For years we have made our porous paper impervious to ink by coating it with size—a kind of thin glue. Paper, until it is sized, is just like blotting paper. The house decorator often uses size to block up the pores of plaster and of woodwork to prevent his pastes, his paints, or his varnishes from soaking into the pores. If he did not do this he would need much more paint or varnish, both of which are much dearer than size.

Perhaps you have noticed that jams and marmalades and syrups are not always stored in tin or glass vessels. During the war the metal was required for other purposes and cheap glass was not obtainable in large quantities. Civilians had to make shift, and porous cardboard, rendered impervious by a coating of wax, was made up into vessels like the tin ones previously in use.

Glazing. Flower pots such as are used in gardens are made of baked clay and are quite porous. Many flower-pot saucers on the other hand are made impervious to moisture by being *glazed* or coated with glass on the inside. Cups, saucers, jugs, basins, jars, vases, are all made of porous material covered with a layer of glass.

This glazing of pottery is a special part of the potter's work.

Porosity, with its consequences, is before us whichever way we turn. Even we ourselves are porous. When we get hot, the perspiration stands in drops at the openings of our pores.

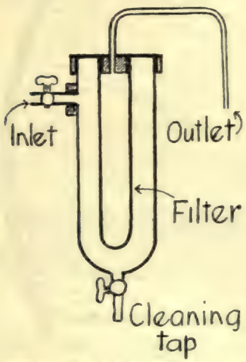
Sponge. In the case of sponges, a number of minute pores seem to have run together and made larger ones which are quite visible to the naked eye. They are really canals and tiny sea animals live in them, for sponges grow on the bottom of the sea in the warm waters off the coasts of Turkey and of Florida. Sponges can take up into their pores a large amount of water. Perhaps you have read Aesop's fable of the ass, the salt, and the sponges.

Pumice. Then there is pumice stone, which is full of holes. This is a wonderful substance. It was once part of the interior of the earth, but has been thrown out as a liquid during the eruption of a volcano. Pumice is the froth that was formed on the top of the molten rock. Some people place it in paraffin until its pores become full of the oil and use it as a fire lighter. It can be used over and over again by resoaking it when the paraffin has burned off.

The rocks of the surface of the earth vary a great deal with regard to porosity. Water can easily make its way through some of them; others are impervious to water. Hard rocks like granite, and even the soft rock we call clay, will not let water pass through them, but rocks like sand and gravel let the water pass easily. Indeed earth acts as a filter and the degree of porosity of certain parts of it regulates our water supply.

Filters. Our drinking water is collected in great lakes or reservoirs, but before it reaches our taps it has to be

filtered—that is, it has to be passed through a thick bed of sand, and "strained" so that the impurities floating in the water are kept back, while the water sinks through the sand. Pipes with holes in them are laid in a stony layer below the sand. The water flows into the holes and so to the pipes. Every waterworks has a set of filter beds arranged side by side, so that while three or four are in use, the others can be cleaned out, fresh layers



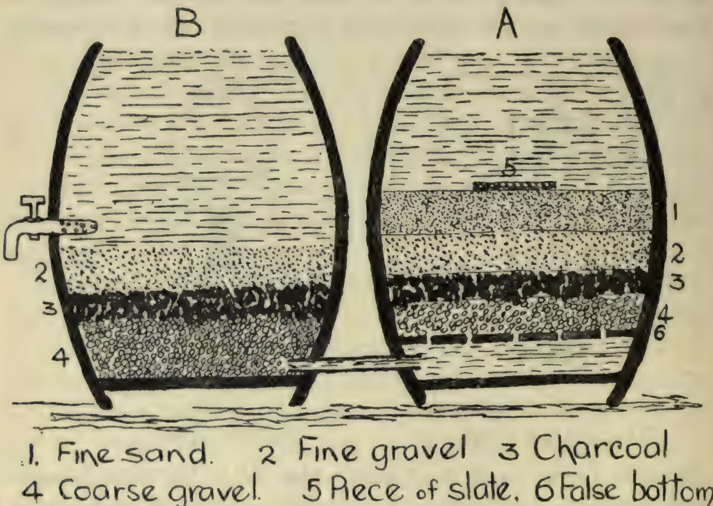
The Berkfeld Filter

A Souchon Filter

of sand being used to replace the old. In some chemical works coke broken into small pieces is used as a filter bed.

In many houses, at railway stations, and on long distance trains, small filters ensure a pure water supply. At one time charcoal was used in these filters; but it has been found that when they have been in use for a short time the water that comes out for drinking is more impure than the water put into the filter—the germs had multiplied to such an extent! Porous earthenware filters have largely replaced the charcoal filter, and that invented by the great Frenchman, Pasteur, is now much used. The water to be filtered enters a case enclosing

a porous earthenware tube, and from the inside of this earthenware tube a tap leads to the outside from the top. The water *has to be forced* through the pores of the filter and the impurities are left on the outside surface. The porous vessel can easily be taken out and cleaned. The Berkfeld filter is on the same principle.



A CAMP FILTER

A simple and effective filter can be made for household purposes from an inverted lamp chimney, such as the one shown on page 37, packed with cotton wool at the neck, a piece of muslin keeping the wool from dropping out. Another Frenchman named Souchon first used this idea.

Soldiers, when on the march, have frequently had to use impure water to quench their thirst. They have kept back some of the impurities by folding up their handkerchiefs and drinking the water after it has passed

through the several layers—but, of course, such a contrivance does not form an efficient filter.

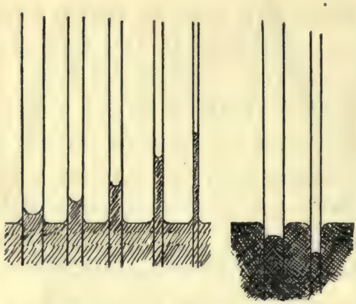
In camps where the water supply is considered not pure enough to drink, rough filters are fitted up. Two casks are arranged as in the sketch. The impure water is put into cask A. It passes down through the purifying layers and rises in cask B, from which it is drawn off by the tap shown—fit to drink.

Bogs. You know that there are bogs in many parts of Ireland. These owe their existence to the fact that there is a layer of porous material overlying a layer of non-porous material, arranged something like a saucer. The water cannot sink away, and the porous nature of the layer in which the water lodges prevents its drying up.

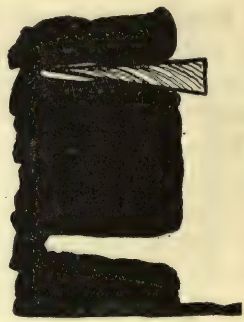
Capillary Tubes. If we place a very narrow glass tube upright in water we notice that the level of the water inside the glass tube is above that of the water round about it. The narrower the tube the higher does the water rise. This strange occurrence is due to what is called "capillary attraction." The word *capilla* is the Latin for a hair, and hairlike tubes all behave in the same way.

Now in taking a single tube we have taken the simplest case we can find ; but the pores in a substance are joined together and form irregular tubes. As this is the case we should expect the water to behave in much the same way in a substance full of little tubes as it does in the case of one tube. If the liquid wets the substance it will rise in the capillary tubes. If, on the other hand, it does not wet the substance it will not rise in the tube. This may be seen by putting a narrow glass tube into a little mercury, when it will be noticed that the level of the mercury in the capillary tube is below that outside. Surface tension, of which we shall learn something later on, has much to do with this.

Porosity and capillary attraction together have played a tremendous part in everyday life at all times. The Romans were great builders and roadmakers, and considering that they had no explosives with which to get their stone from the quarries you may wonder how they did it. They cut the rock round the piece they wished to dislodge. Then they drove wooden wedges into the upper



Capillary Tubes in Water and Mercury

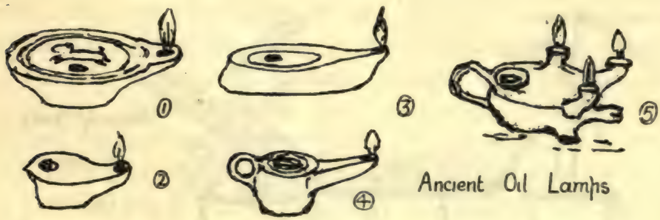


A Roman Wedge in use

cutting. The wedges were, of course, porous. They then poured water on the wedges. The millions upon millions of tiny pores drew in by capillary attraction an equal number of tiny drops of water, and the wood became so swollen that the rock was broken out.

Lighting. One of the earliest means of procuring artificial light was the lamp, which was used long before the candle came into use. We find lamps in the tombs of the Egyptians of Pharaoh's time, and of other Empires long since gone. They were usually shallow vessels like our sauce boats with a wick floating in oil. The wick was porous and the oil was drawn up by capillary attraction to burn at the end as in our lamps of to-day. Much the same kind of lamp is still used by the Esquimaux.

Wicks are made of various porous materials usually obtained from plants. Candle and lamp wicks are of plaited cotton. In olden days when candles were first made the wicks were of pith from the inside of rushes, and the first candles were called " rush " lights.



Syphons. Nowadays we use wicks on engines of all kinds to oil the engine. A wick is put into a cup of oil. The oil passes along the wick by capillary attraction, and drips off the end on to the machinery to be oiled.

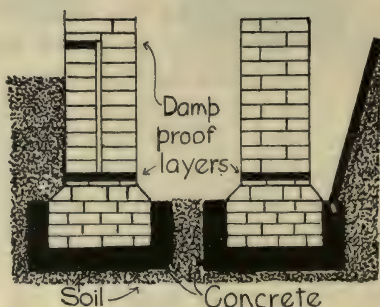
Some people use the same kind of device, when they are off for their holidays, to keep their plants watered while they are away. They take a large bowl of water, mount it on a box, and put the plants round it. Then for each plant they put a strand of wool with one end in the bowl and the other hanging over the side. The water is drawn up slowly and drips on the plant, so keeping it moist.

Have you ever heard of the Spanish Inquisition? Those who lived in the days when Spain was at the height of her power, lived in constant terror of being taken before the inquisitors, who often condemned both men and women to horrible torture for very trivial offences. One of the tortures was that of " dripping water." The victim's head was shaved, he was fixed immovably in a chair, and at a height above his head was placed a bowl of water, a thread of worsted hanging over the side from

the bowl. The water passed along the wool and dropped slowly on the victim's bare head. Each drop falling from a height struck with some force, and then trickled over the skin, slowly evaporating. The victim usually went mad under this treatment.

Watering Plants by means of a Capillary Siphon

Oiling by Capillary Attraction



Damp proof courses in walls of houses

Warped Wood. Woodwork warps a lot with changes of weather. Boards unprotected from the weather shrink and crack under the heat of the sun, but in rainy weather the moisture causes them to expand and bulge, and the structure of which they form part may be spoilt.

Next time you see a house being built, examine carefully

the part where the brickwork comes above the level of the ground. You will then see what the builder—if he he is capable and honest—does to protect the house from damp. When the bricks are about a foot above ground he puts in a " damp proof " course. The bricks of the foundation being porous will take up moisture from the soil, and this if not stopped would spread upwards making the walls of the rooms damp. Asphalt is usually employed for this purpose and the layer is generally half an inch thick. Sometimes a layer of glazed terra-cotta brick is used. Slates may be used for the same purpose. Two layers are placed so that those in the top layer cover the joints of those in the bottom layer.

Railway Sleepers. Railway sleepers which are often in contact with wet earth, however well drained the track may be, are usually soaked in creosote—an oily substance obtained from tar.

The sleepers are put into a cylinder, the end of the cylinder is then closed, and all the air taken out. This leaves the pores of the timber quite empty. Then warm creosote is run into the cylinder and as there is nothing to stop it the capillary attraction of the wood pores draws the creosote into the timber. To save time and to make the process more thorough, air is forced into the cylinder and this presses the creosote further into the pores. Sleepers treated in this way will last for years.

We preserve our boots in a similar way. The leather is porous and to keep the wet out we soak the soles in oil (boiled linseed oil). The oil occupies the pores and the water cannot get in. The tops of boots are rubbed with " dubbin."

Catching the Hippopotamus. One of the strangest uses to which man puts this property of porosity is found in

the upper parts of the Nile. There, the natives note the places that the hippopotamus visits, and they put for him to eat a large quantity of pease. He likes pease—and eats and eats till he can eat no more. That makes him thirsty and he drinks and drinks till he can drink no more. The pease is porous and the water goes into the pores and makes it swell. Then he swells and swells till he can swell no more and, to put it gently, he dies from overfeeding.

The same property, is used on a smaller scale by the farmer. Often he has to walk through wet grass and his boots become saturated. At home he takes them off and fills them with oats. The oats absorb the moisture and dry the inside of his boots. At the same time they swell and keep the boots in shape.

SOMETHING TO DO

1. **To Show Card, Cloth, Paper, etc., to be Porous.** Over a vessel of hot water put a piece of card (or cloth, etc.). Over the card invert a cold tumbler, as in the sketch. Steam passes through and is condensed above.

2. **Match and Coin Trick.** Choose a button (or threepenny piece) that will drop into a bottle. Support it as shown by a broken-back match. To put the coin into the bottle without touching it, put a drip of water at the break in the match stick.

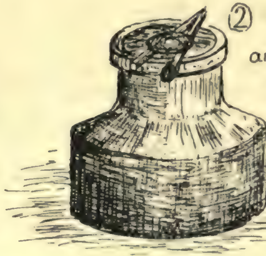
3. **Capillary Plates.** Two pieces of glass (microscope slides —old photo plates), a match stick, and elastic band. Fix as shown, dip into coloured water and note what happens.

4. **Capillary Syphon.** Use worsted or lamp wick, to water plants (p. 42).

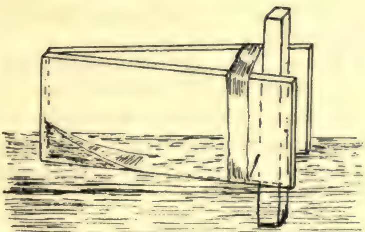
5. **To Make a Reservoir Pen.** Open a brass or tin paper fastener. Push one end into penholder at the back of the nib, and let the other end rest on the back of the nib towards point.

6. **Souchon Filter.** Lamp glass with muslin cover held on by tight elastic band. Pack lower end with cotton wool—mount in any convenient way.

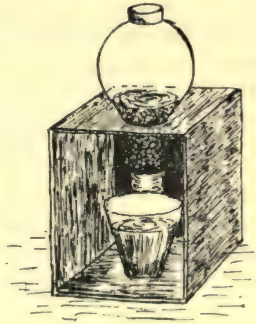
① To show Porosity of Card



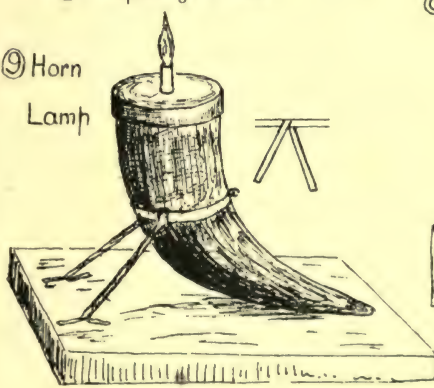
② Match and Coin Trick



③ Capillary Plates



⑥ Souchon Filter



⑨ Horn Lamp

⑦ Flowerpot Filter

7. **Flowerpot Filter.** Stop the hole with a sponge, put in a layer of coarse flower pot material crushed (or coarse sand), then a layer of finer material (or finer sand), then a layer of flower pot material crushed to dust (or silver sand). Place a small piece of slate (or a piece of flower pot) on top of which to pour the water.

8. **Porosity of Soils.** To find the amount of air in a given quantity of soil—

(1) Fill a jam jar with water, and pour the water into a jug to measure the quantity.

(2) Fill the jam jar with soil.

(3) Pour the water slowly into the soil until the water appears at top of the jar.

(4) The amount of water poured out of the jug equals the amount of air contained previously in the soil.

9. **Horn Lamp.** A cow's horn. Tin lid to fit, having a hole through its centre and through which passes a tin tube about 1 in. long carrying the wick. Place a band of ½-in. wide tin strip round middle, fixing the legs on band before fastening. Twist band ends to give a good grip. Soak wick with oil, as no loose oil is to be provided.

CHAPTER IV

Elasticity

> "What of the Bow?
> The bow was made in England,
> Of yew wood."
>
> —*Song of the Bow.*—Kipling.

Archery. It was the longbow that won for us the fights of Crécy, of Poictiers, and of Agincourt. There were no archers to be compared with the English archers. And their bows? They were simple enough to look at. Just a piece of yew wood—or ash—about six feet long, carefully seasoned and carefully shaped, but possessing that wonderful power of recovering its shape from pressure or bending, which we call "elasticity."

Elasticity is one of those properties of matter that almost every race has turned to use in some way or other. Some of the very earliest pictures in existence, brick pictures, show warriors of the Babylonian Empire and give prominence to the bowmen. We read of the bow quite early in Bible history. Ishmael became an archer; Philistine archers overcame Saul; David commanded the use of the bow to be taught: "And he bade them teach the children of Judah the use of the bow."

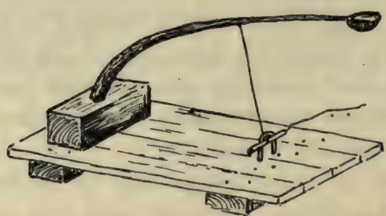
Harold, William Rufus, Richard I, were English kings killed by means of the bow.

So powerful was the English longbow, that it shot an arrow a yard long over a distance of three hundred to five hundred yards—over a quarter of a mile. That archers could shoot straight is proved by many stories, such as those of Locksley's feat in *Ivanhoe*. The bow did not cease to be officially used as a soldier's weapon

in England until 1599, towards the close of Elizabeth's reign.

We find the bow in use among the wildest tribes of Asia, Africa and America. It is even on record that during *this*, the twentieth century, one of the Indian tribes of Mexico, armed with nothing more powerful than the bow and arrow, was able to inflict a bad defeat upon a Mexican force armed with the modern rifle and machine gun !

During the Middle Ages, the Genoese became famous bowmen. They used a crossbow—a much stiffer and

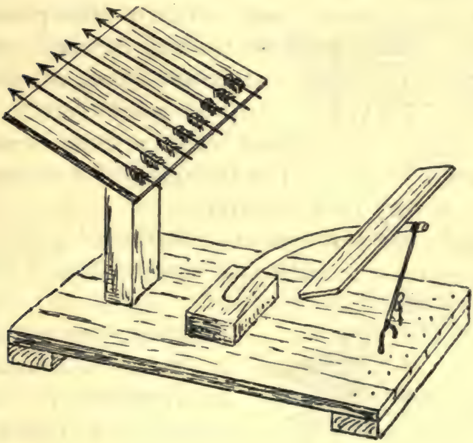


A Trench Mortar

smaller bow than the longbow. It was mounted on a stock that looked something like our gun and was so stiff that it had to be drawn by machinery. It was slow to " load " and on that account was less useful than the longbow.

Artillery. Our word " artillery " probably means to most people the big guns which have been in use in the Great War. But the word comes down to us from the Romans who had no guns—yet they had artillery in the shape of machines for hurling great stones upon their enemies. In their simplest form these "great guns " of the Romans were made of an elastic pole with a basket attached to the free end, the other end being firmly fixed to a platform. The pole was bent down more or less, according to the

weight of the stone placed in the basket and the distance to which it was to be thrown, by means of a rope arranged as in the sketch, When the trigger was pulled, the pole's elasticity straightened it out, and in doing so, hurled the stone from the basket. Strange as it may seem, both the Germans, and the Allies, used almost the same kind of machine during the Great War for hurling explosives



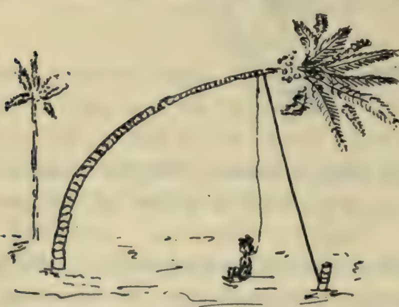
A Roman Machine Gun

at each other across No Man's Land. So the earliest form of trench mortar was just a replica of the old Roman artillery piece.

The Romans, too, had a kind of machine gun, which depended for its working upon elasticity of bending. A sloping platform had a number of grooves in it, into each of which an arrow was placed, the feathered ends of the arrows projecting a little at the back of the platform. A wooden slab mounted on an elastic pole was drawn back and then released. On springing into position it discharged all the arrows in a flight.

Springs. The " machine guns " and " artillery " were moved from place to place on carts very unlike ours. They had no springs to make their running easy—nothing to lessen the effect of the jerks and jolts of the road. Nowadays every cart is fitted with springs—so is every railway carriage and waggon and engine. It is these springs that make travelling so comfortable and speedy. The springs mostly used are called " leaf springs," and are made up of several strips of steel placed one on the other. Those used on railway carriages are put through a most thorough test before being allowed to come into use. They are " turned inside out." If they come back exactly to their first shape without breaking, they are passed for use. The breaking of a railway carriage *spring* is a very rare occurrence.

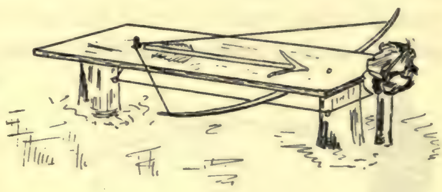
A fishing rod is another example of a substance "giving" when a strain is put upon it and recovering its shape when the strain is taken off.


Execution in the South Sea Islands

A very strange use is made of young palm trees in the South Sea Islands. A prisoner of war, or some other poor victim condemned to death, is made to sit on the ground. His hands and feet are tied together and he sits like a letter L. The young palm tree is then bent down by several men pulling a rope attached near the top. When bent as much as possible, the tree is tied down to a peg in the ground. Another rope is attached

to the top of the tree, the other end of it being tied round the victim's neck. When all is ready the " medicine man " fixes a lighted torch to the rope holding the tree down. When the rope is burned through, the tree springs up and the victim is executed.

Tiger Trap. Traps, making use of this power of recovery from bending, have been used for ages past in many different parts of the world. The tiger has been a pest in Indian villages for centuries and the natives have devised many ways of catching him. One is by using a bow and arrow. A narrow board some six feet long is taken. Across it, near one end and below, is fixed a powerful bow. Near the other end is the trigger. The arrow is put in place. The bait, a piece of kid perhaps, is placed in front of the board and about a foot in front of the arrow. The bait is tied to a string which is fastened to the trigger. You can guess what happens. The tiger takes the bait and gets the arrow thrown in ! The trapper, of course, arranges so that the tiger can get at the bait only from the front.

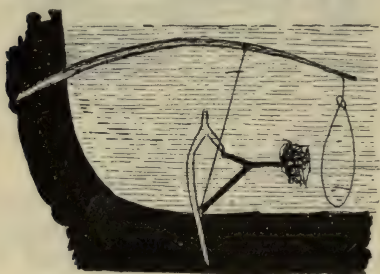


Indian Tiger Trap

Beaver Trap. Beavers are also taken by a spring trap—the spring being an elastic branch of a tree. The trapper fixes the pole into the bank, bends it and fixes it down under water. He hangs a wire slip noose at the end. The bait is attached to the trigger holding down the rod, so that the beaver can get at the bait only by putting his head through the noose. The beaver comes,

seizes the bait and is caught in the trap. Rats and mice are taken in traps that work on this same principle of the elasticity of bending.

I wonder how many locks there are in the room you are in? Probably every one of these locks in its mechanism makes use of the elasticity of steel. Clocks and watches, too, depend for their action upon steel springs. Some years ago, a captain who had broken the mainspring of his watch while on a voyage to Yokohama, took it to a Japanese to have it repaired. A few days later he received back his watch in going order, and set off on his return journey. But his watch behaved in a very strange way. Curiosity made him take it to pieces to see what had been done to it. He found that a mainspring of bamboo had been put in. It was, of course, much weaker than the broken steel spring had been, but the contrivance was very ingenious.

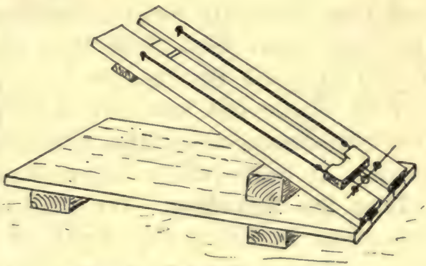


Beaver Trap— set under water

The Japanese uses bamboos, too, for his queer umbrellas and sunshades, but the ribs have not nearly the same elasticity as the steel ribs of our umbrellas. Before steel became cheap, whalebone was used in England for umbrella ribs as well as for numerous other things in which an elastic substance was needed.

Trench Catapult. If you were asked to name an elastic substance I suppose you would at once say "elastic." Most of you have handled elastic. If you stretch it,

it goes back to its former shape or size. Catapults are made from it, even catapults on a large scale. Besides the " trench mortar " mentioned earlier, our men made a catapult for throwing bombs into the German trenches. It was similar to those used by boys, but much more powerful. The two elastic sides were attached by their upper ends to a pair of parallel boards, and a movable wooden pocket fitting across the space between the boards was fastened to the other ends. The two boards were hinged at their lower ends to a wooden platform, and could be set at any angle. The pocket had a ring in its back so that it could be fixed down by a peg when the elastic was stretched. The bomb was placed in front of the pocket, the pin quickly withdrawn and the elastic of the catapult threw the bomb.



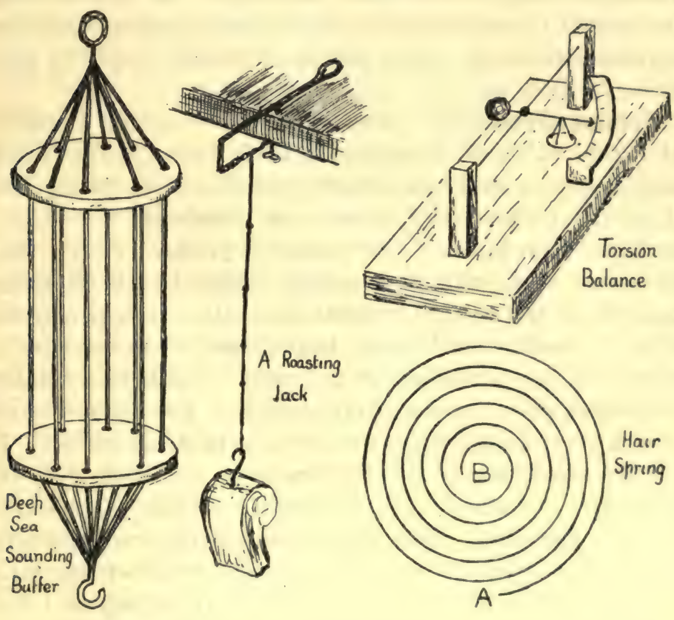
Trench Catapult

But elastic is not really a good elastic substance. This may sound strange, but if you stretch and release it again and again, you will find it loses the power to recover its shape. If you stretch it too much it snaps. This is true, also, of a piece of wood or of any other elastic substance. All elastic substances are elastic only up to a certain point, and then they give way. Elastic itself can be stretched a great deal before it gives way and we say its range of elasticity is great. You would hardly think glass was elastic. So is a steel ball such as you see in use in bicycle and motor-car wheels. An elastic substance is one that strongly objects to having its shape altered,

and quickly recovers its shape after being knocked or pulled or pushed or twisted out of shape, and that will do this any number of times. Take a glass marble and a piece of plate glass. Smear the plate glass with printer's ink, or oil and soot. Stand the glass marble on the plate glass for a second. Look at the little black dot on the marble on lifting it. Now wipe it off and drop the marble from a height of a foot. Catch it on bouncing and notice the size of the black dot. It is much larger than the first. Yet both glass and marble are as smooth as before. The glass altered its shape when the two came together, and that accounts for the increased size of the spot. But you could soon show that the glass would break, if you dropped the marble from a greater height. It is very elastic but has only a short range of elasticity. It is compressed on striking and extends again on moving away. An india-rubber ball undergoes similar changes.

Deep Sea Sounding. We shall see later why it is so important to know the depth of the sea at different places. Some years ago the British and the American Governments sent ships to learn what they could about the floor of the ocean. They sounded its depths, but often in rough weather the ropes were snapped by the sudden lifting of the ship by the waves, which strained the rope carrying the weight so much that it snapped. To avoid this the crew of the English ship—the *Challenger*—fitted an elastic support for the rope. It was made of two plates of wood. An equal number of holes were made round each. Through these holes were passed stout elastic rods, which were all tied together above the top plate, and below the bottom plate. The upper knot was attached to the yard arm, the lower carried the wheel over which the deep sea line went. When the ship heaved the rods stretched and the strain was not put on the rope too suddenly.

Roasting Jack. You may have read in your history books the story of Lambert Simnel, who was the leading figure in a rebellion against Henry VII. After suppressing the rebellion Henry VII made Simnel a scullion in his kitchen, where his chief duty was attending to the turning of the meat while it was roasting, for in those days there



were no gas ovens. Not only in kings' palaces, but in every humble home the "roast beef of old England" turned in front of open fires. The king and his nobles employed dogs for this work. To show his contempt for Simnel the king gave him dog's work to do. In the humbler homes the *jack* for turning the meat was a much simpler arrangement than the king's, and is still in use.

It consists of several strands of worsted or string knotted together at intervals of six inches. One end was attached to a bracket often fixed to the mantleshelf, the other carried a hook from which the joint was hung. To set the jack working, a twist was given to the joint. It wound up the worsted till it could twist it no more. Then the weight of the joint unwound the worsted and the inertia of motion of the joint twisted it up again in the opposite direction. This inertia of motion kept the jack going quite a time.

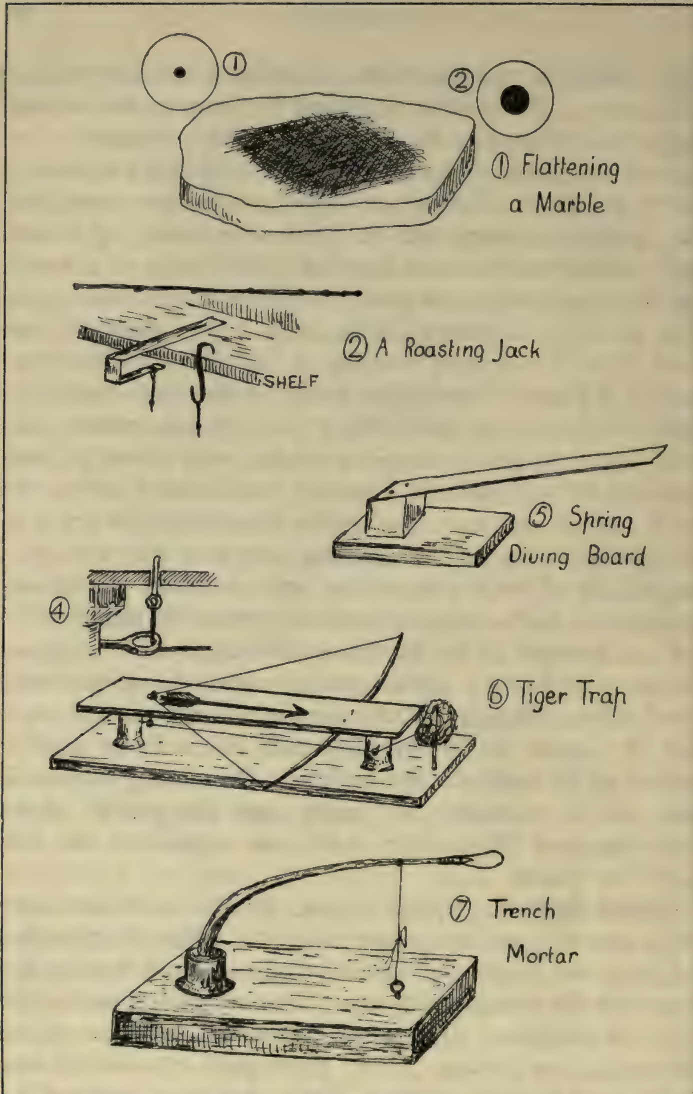
Torsion Pendulum. Now this gives us an example of a kind of elasticity of which little notice is taken but which plays a most important part in our everyday life. It is the elasticity of torsion or twisting. You have, perhaps, seen in the clock maker's window, clocks that go for a year without winding. This has been made possible by the use of torsional elasticity. The pendulum of a "grandfather" clock beats slowly—about once a second. The pendulum of a "year" clock beats much more slowly—it takes several seconds. Yet it is not at all a long pendulum, being generally less than six inches. It is a fine wire fixed to the top frame of the clock. At its lower end it carries a heavy weight—a brass plate sometimes. The plate turns slowly backwards and forwards just like the meat on the roasting jack, twisting and untwisting the wire. On the wire near its top end is a catch which lets the clock unwind very slowly indeed.

Torsion Balance. One of the most delicate kinds of balance we know is the "torsion" balance. It consists of a thin stretched wire arranged horizontally. Fixed firmly to it at its middle, and at right angles to the wire, is a very light arm. If a very tiny weight be put on the outer end of the arm, it sinks and twists the wire. On removing the weight the arm goes back as

the wire recovers its shape on account of its torsional elasticity. The weight is found by noting the amount of turn. A hair can be weighed on such a balance.

Another form of torsion balance, a spring balance, is often used in the kitchen, to save having a set of weights. It contains a long elastic steel wire made up into a coil. Imagine that you have the hair spring of a watch on the page before you with the end A fixed to the paper (*see* p. 55). The wire AB is only bent. Now lift the end B off the paper, keeping it exactly over the spot where it rests. You are not curling the wire any more but twisting it as you lift it up. If you release the end B the torsional elasticity of the wire draws it back into its former position. In the usual coiled spring the coils are all one size, one under the other. When you lengthen the spring you do not lengthen the wire, you merely twist each part of the wire a little, the spring going back to its original shape, as soon as the pull is taken off, on account of its torsional elasticity. In the spring balance we have a coiled spring made of highly elastic steel wire. The upper end carries a scale pan or hook for the goods to be weighed and has a little pointer attached to indicate the weight. When any object is put on, it squeezes the spring and the extent of the movement of the pointer shown on a scale at the side gives its weight.

Spiral Springs. Spiral springs of the same kind are very largely used for many purposes. The safety valve of the steam engines is regulated by one which is squeezed back by the escaping steam. You will find them on the sides of tramcars supporting the weight of the car and lessening the jolting. They form part of some of the buffers of railway trucks. Bolts are often worked by the torsional elasticity of spiral springs. Other cases,


① Flattening a Marble
①
②
② A Roasting Jack
SHELF
⑤ Spring Diving Board
④
⑥ Tiger Trap
⑦ Trench Mortar

such as toy guns, will occur to you, and you will understand how very useful is this property of torsional elasticity. Ropes and cords, cottons and threads, depend upon torsional elasticity for their construction.

Elasticity, whether due to bending, to stretching or compressing, or to twisting, plays a most important part in our daily lives.

SOMETHING TO DO

1. **Flattening a Marble.** A piece of plate glass smeared with printer's or cyclostyle ink, or oil and soot. Use a glass marble. (1) Marble at rest shows small black dot; (2) Dropped from a height of 1 ft. and caught on rebound it shows a larger dot.

2. **Roasting Jack.** Two or three strands of string or worsted knotted together as shown. A meat hook or a stiff wire bent into shape to hold from shelf.

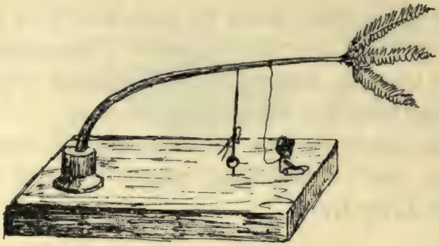
3. **Catapult,** as used for scaring birds; **Y** twig. Two 6-in. lengths of elastic (about $\frac{1}{8}$ in. square or diameter if round); piece of kid glove to hold stone. Bind the elastic with thin elastic, one end of each piece to each arm of the **Y**. Bind the other ends with thin elastic to the piece of kid. (Why is elastic used for binding instead of string?)

4. **Bow and Arrow.** Made from cane, bamboo, umbrella rib, etc. Arrow from flower sticks. Fix a paper "feather" in a 2-in. slot cut in the end of the arrow, and bind up the end again.

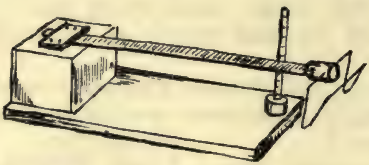
5. **Spring Diving Board.** Base, wooden block, piece of venetian lath or other thin wood. Slope top of wood block with knife and sandpaper. Fix as shown.

6. **Tiger Trap.** Base, two cotton reels; arrow board with hole for trigger near one end; bow (prepared as in 4) rests in two nails bent like **L** and driven in under the arrow board —or tie to front reel. Trigger, a piece of thick copper wire bent into an eye at the end. String from trigger passes through screw eye in back reel to bait in front of arrow. Arrow from a penholder. Fix up as shown in sketch.

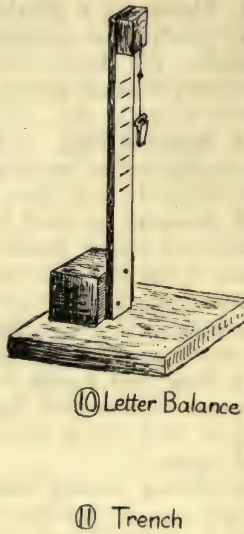
7. **Trench Mortar.** Base, half cotton reel, screwed firmly



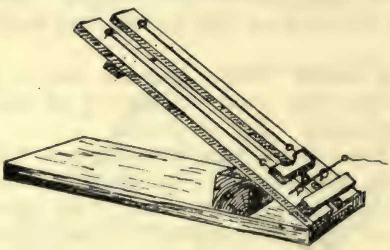
(8) Execution in the South Sea Islands



(9) Letter Balance



(10) Letter Balance



(11) Trench Catapult

from below ; cane (or other elastic arm) with a wire loop bound to the end as a basket ; screw eye, bent nail or staple. Fasten down with a slip bow.

8. **Execution in South Sea Islands.** As above. Make leaves of paper or rag. Cut a " victim " from a clothes peg ; take off legs and fix on loosely, add thin strips of wood for arms. Fix and work like the trench mortar.

9. **Letter Balance (Bending).** Block and base, and crinoline steel or other elastic material ; two corks ; wire cradle for letter. Make a scale by trying various known weights. One cork carrying cradle is fixed on the end of the crinoline steel ; other cork carries the scale and is glued to the base.

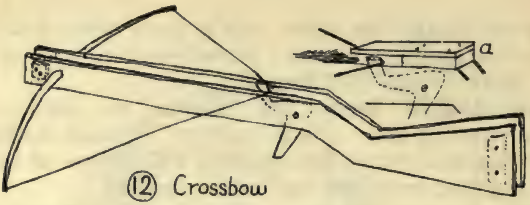
10. **Letter Balance (Stretching).** A piece of thin elastic with a knot tied in it and carrying a tie clip or wire paper fastener. Fix, as in sketch, the knot opposite ° on scale.

11. **Trench Catapult.** Base, block movable to any position. Two guiding strips of wood mounted with space between and hinged by tape or thin leather at lower end (or small hinges, if at hand). Wooden pocket to hold "bomb," with two screw eyes fastened to front and one at back ; four other screw eyes, one at each end of guides, as shown. Elastic is fixed from front eyes to eyes in pocket. Draw back the pocket, and push a wire through the three eyes to hold it back. To work, put a marble in position in front of pocket, pull wire out sharply.

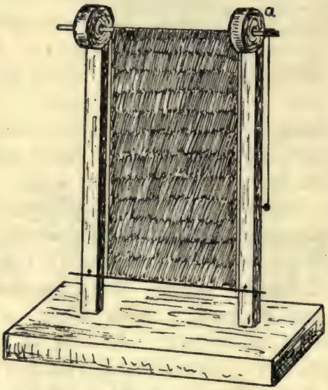
12. **Crossbow.** Shape the two sides alike, and separate them by a space less than the thickness of the arrow (pen-holder). The trigger cover (*a*) keeps the string from clearing the arrow without discharging it.

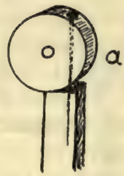
13. **Roman Machine Gun.** The sketch on page 49 shows the construction. Use crinoline steel or cane for driving the arrows. In a small model the arrows can be made from match sticks.

14. **Spring Roller Blind.** Mount sections of cotton reel as shown. The nail must not cross the hole in the reel. The roller is a penholder with a slot cut along the axis at one end. Make the blind of paper gummed to roller. Two nails keep the blind down. When the blind is up, the elastic stretches from the nail in the side post to the slit cut in roller. The elastic is drawn through the slit and knotted above. As blind is pulled down, the elastic is wound on the roller.

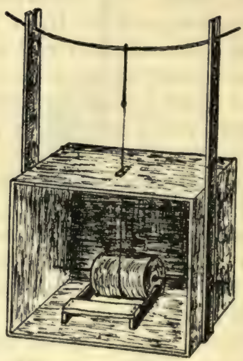


⑫ Crossbow

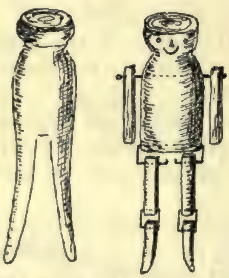




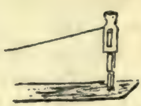
⑭ Spring Roller Blind



⑮ Bow Saw



⑯ Jollyboy



15. **Bow Saw.** Box with hole cut in one side as shown; two side-pieces with slots at top to carry crinoline steel bow. A knitting needle carries the reel with the treadle attached as shown. The saw (fret-saw blade) is wired to the bow and to string attached to the reel, and passing under it to far side. (Why is a reel used, and the wire not attached straight to the treadle?)

16. **Jollyboy.** Clothes peg made into a loosely-jointed doll. A skewer in the doll's back holds it with feet touching a springboard, e.g. the spring diving board, No. 5 above. Tap the board to make the doll dance.

CHAPTER V

Tenacity

Spiders' Webs. At the fall of the year, if we look round our gardens, we see on the taller plants large spiders' webs. They are more noticeable in September and October, because of the dew which settles on them in the cooler nights. At this time of the year, too, we are often visited by high winds, corresponding to the March winds near the beginning of the year, and we wonder that such fragile things as spiders' webs can survive Nature's rough treatment. But they are wonderfully strong—even in the case of our English spiders.

If we go to hot countries we are still more astonished. Some of the monstrous webs made by spiders in the tropics are about a yard across and are made of strands as coarse as thread. So strong are these webs that they can arrest the flight of the largest moths and butterflies of those parts, and, as you may know, some are very large. Some webs are strong enough to entrap small birds. One kind of spider in Senegal spins a thread so strong that it can support a quarter of a pound weight. A traveller from America tells us of a fight between a spider and a small snake, in which the spider won! It was able to bind the snake up with its strong silk-like threads just as our small spiders bind up our largest flies. This wonderful power to resist being broken is called "tenacity," and is due to a force that holds the particles together, called the force of cohesion.

Tenacity and Cohesion. The same power is found in the thread of the silkworm. It is wonderful what tenacity such delicate material has. It is stronger than

steel threads of the same thickness would be. But it is wrong to say the silk comes from a worm. The silk really comes from the caterpillar of the silk moth which originally lived only in the Far East. The way silk came into Europe is very interesting. Chinese records tell us that Hoang To, who lived about the time that Joseph went into Egypt, first discovered how to work the silk threads into silk fabrics. From China the art seems to have gone to India and Persia, and it was from Persia that the Romans got their first silks. At that time, silk was so very expensive that kings could not afford to wear it. Then two monks from India went to the Roman Emperor Justinian, and declared they could tell him all about silk. They told him it was illegal and therefore impossible to bring the worm alive to Byzantium, that the breeding was quite easy, and that each parent animal produced many eggs which were hatched by the heat in manure. The Emperor promised them a reward if they could bring some eggs. This they did, hiding the eggs in a hollow bamboo to bring them out of the country, for if they had been discovered removing the eggs, it would have been certain death for them. From that time the silk industry in Europe has progressed, and now many millions of silkworms are reared in the warm parts of France and Italy. In 1710 a Frenchman made stockings and gloves from spiders' webs, but found that twelve spiders were required to do the work of one silkworm. Nowadays silk is obtained from a number of sources, but no thread is as tenacious as the thread of the original silkworm.

Cotton. Another tenacious fibre is cotton. An old historian, named Herodotus, tells us of " wild trees that bear fleeces as their fruit, surpassing those of the sheep in beauty and excellence, and the Indians use cloth made

of this tree wool." The cotton fibre is not nearly so tenacious as the silk, yet it makes quite strong fabrics. When Columbus discovered America he found the natives not only had the cotton plant, but knew how to make it up into fabrics, and cotton clothing was in common use among them. It is difficult to realize that, in 1721, laws were passed in England imposing a fine of £5 upon anyone wearing cotton, and a fine of £20 upon anyone who sold it! It was thought it would be the ruin of England, as it was replacing wool, then one of the principal productions of this country. Now cotton goods are our principal export. How things change as people get wiser!

Hemp. There have been times when prisoners have escaped by means of ropes made from cotton sheets torn into strips and twisted; but ropes are generally made of hemp. Hemp is a plant growing in districts at the east end of the Mediterranean sea. Most of the rope cordage about ships is made of hemp. Hemp ropes, when wet, shorten a great deal and swell, and are not so tenacious then as when dry.

Rocket Apparatus. Hempen ropes are used in connection with the rocket apparatus for life-saving around our coasts. When a vessel strikes the rocks near the shore, the water is, as a rule, too rough to allow the life boat to reach her. A rocket carrying a light hempen cord is fired in the direction of the ship. The sailors on board catch and pull in the light hemp cord which has a much stronger hempen rope attached. This is fixed firmly to the wreck. On this thick rope a life buoy—or breeches buoy—hanging from a pulley is worked backwards and forwards from shore, and the shipwrecked sailors are drawn safely to land over the "rope bridge."

Bridges. Rope bridges of another kind are found in

Photo by courtesy of *Commander A. S. Chambers, R.N.*

COASTGUARDS ARRANGING A LIFE-SAVING ROCKET
APPARATUS BEFORE FIRING

daily use in some parts. For example, one of Ireland's curiosities is the rope bridge at Carrick-à-rede, an island sixty feet from the mainland. It is separated from the mainland by a chasm eighty feet deep. This is spanned by a very simple suspension bridge of rope. Another something like it is found across the cracks in the volcanic rocks of Iceland. Suspension bridges are usually much more elaborate and are suspended from *wire* ropes or chains. Steel wire has largely replaced iron wire because of its greater tenacity or tensile strength—that is its power of resisting force which tends to make it break. Suspension bridges are single span bridges, like that at Carrick-à-rede, but the footway in that case is on top of the ropes spanning the gap. They are now built with the roadway hanging from the great wire cables stretching from the top of high steel towers at each end of the bridge. The ends of the cables have to be very firmly fixed into the ground. Many hundreds of tons of stone are often used for this purpose. When the cables are ready the roadway is built out from either bank, the road hanging from the supporting cable by iron rods or chains.

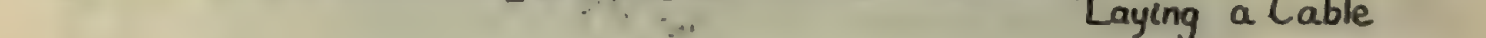
Wires. Wires of all kinds—steel, iron, copper, brass—are made by taking strips of the metal to be made into wire and drawing it through a set of holes in very hard steel plates. Each hole is smaller than the previous one through which the wire was drawn. The wire often has to be made hot during the process of drawing down. The tensile strength of wire is enormous, and the uses to which wire can be put seem to be unlimited. A wire made of plough steel, one square inch in section, would lift one hundred tons without breaking. Actually in use, such a wire would never be given more than ten tons to lift—that is, about one-tenth of the full weight it could

By permission of the Government of W. Australia.

A SIMPLE TYPE OF SUSPENSION BRIDGE OVER THE AVON RIVER AT YORK, WESTERN AUSTRALIA

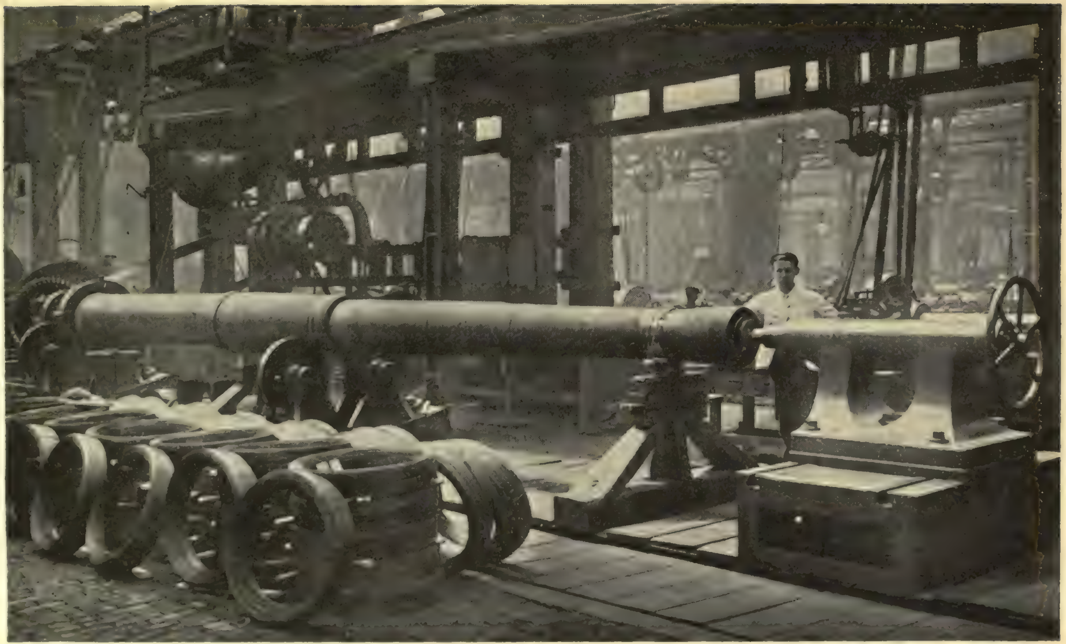
bear. Wires are made up into bundles to form ropes much as hemp is. Such wires—wire cables we call them—have been put to quite a number of uses, among them the raising of sunken ships, when the latter have been lightened as much as possible. On occasions the strain was so great that the wire rope snapped. The havoc caused by such an occurrence is terrific, for a wire rope when it bursts, "mushrooms," i.e. the strands spread out and tear to shreds everything within reach.

Aerial Railways. In many parts of the world the laying of railways is extremely expensive on account of the nature of the track over which the rails would have to go. For this reason, when the traffic is small, aerial railways worked like the rocked apparatus have come more and more into use. Being longer, of course, they have to be propped up at intervals on tall steel supports. In England they are used to convey ores to the railway from the mine.



Laying a Cable

Atlantic Cable. Until a few years ago, all telegraphic messages between ourselves and America passed over the Atlantic Cable. The cable consists of three parts—the central copper wire to carry the electricity, a rubber cover to prevent the electricity from escaping, and the outside steel wires added to give the cable sufficient tensile strength to stand the strain of laying it. For, in deep water, the distance from the stern of the ship laying the cable to the place where the cable touches the



By courtesy of *Messrs. Armstrong, Whitworth Co.*

GUN MAKING—WINDING THE BARREL WITH WIRE UNDER GREAT TENSION

floor of the ocean may be twenty miles. This twenty miles of cable is very heavy and its weight would cause it to break, were it not for the great tensile strength of the wires fixed round it to prevent such a breakage.

Wire-Wound Guns. Another use to which the great tensile strength of wire is put occurs in the making of cannon. A long tube is chosen to be the bore of the gun. Then, to strengthen the rear part where the explosion is to take place, wire ribbon is wound round very tightly indeed by machinery, the wire being under enormous tension during the winding. It is put on as smoothly as cotton on a reel. Then another tube is slipped on over it, round which in turn more wire ribbon is wound, till the required strength is reached.

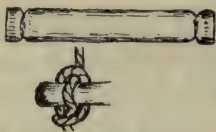
Bowden Wire. If you examine a bicycle you will most likely see somewhere on it a "Bowden wire"—used perhaps for working the brake. It is really a bundle of fine wires running in a wire-made tube. It can be bent in gentle curves without breaking, and one end of the inner wire is attached to the handle, the other to the brake. Whatever pull we give to the handle the bowden wire carries to the brake, however much the wire may be curved from handle to brake.

Leather. Leather is another substance having great tensile strength, and it has been in use for ages past. Hides have been cured and choice pieces taken for reins and traces, and in more recent years for belting to drive heavy machinery. You can realize its strength when you see horses harnessed by leather traces to great carts holding several tons weight. The traces seldom break under the strain of pulling, showing thereby the great tensile strength of the leather.

Lassoes of raw hide are used by the cowboys of America for catching cattle and horses. A plunging bull or a

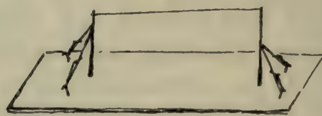
wild horse is not easy to hold, yet the lasso bears the strain. Mayne Reid in his *Young Voyageurs* tells how his heroes were wrecked in the rapids, and managed to scramble from their birch bark canoe on to a rock in mid-stream. They made a lasso by cutting up their skin hunting shirts and tying the pieces together. "To Basil was handed the rope. He took the noose end in his right hand and commenced swinging it round his head, his companions lying flat on the rock. After a few turns the rope was launched at a rock nearer the bank, and a loud 'hurrah!' from François announced that the throw was successful, ... Basil passed over first, as it was but right he should test the strength of the new fashioned bridge of which he was the architect. The rope was stretched to its tension but he succeeded in handing himself along." As the rope bore Basil's weight while the stream was washing against him with all its force, the skin bridge must have had great tensile strength indeed.

Chains. "The strength of a chain is measured by the strength of its weakest link." We have already spoken of the tensile strength of steel in the form of wire. Steel chains must also be noticed, as they are of the greatest importance—especially in shipping. The great anchors of such a vessel as the *Mauretania*, would need ropes of such thickness to lift them that they would be almost unmanageable. Chains, however, can be made much less bulky, much easier to handle, and stronger bulk for bulk, and these now take the place of anchor ropes on our great liners and war vessels. Chains, before being put to use for such purposes, have to pass a severe test in which they must bear a pull much greater than the greatest they are expected to experience when in use. In the making of small chain links, women are largely

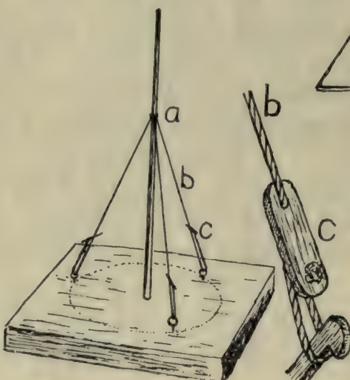


① Rope Ladder

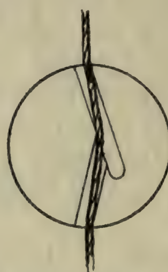
② Cheese Cutter



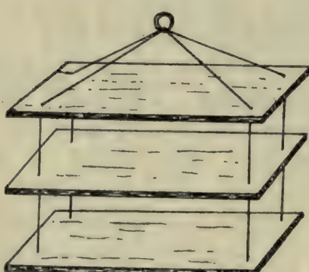
⑤ Clothesline



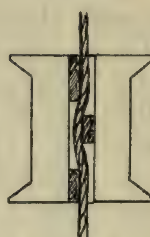
④ Flagstaff



⑦ Obedient Ball



⑥ Bookshelves



employed, but the heavier links of the great chains need men to work them.

Chains are often used to guide ferry boats across narrow channels. There are usually two chains, one on each side of the ferry, and these are picked up as the ferry goes forward and slide down again behind. They serve as a guide in foggy weather, and help the ferry to withstand the set of the tide or stream.

SOMETHING TO DO

1. **Rope Ladder** (12-20 rungs). Penholders cut to desired length; 2 yds. thin twine. Fix rungs in chain stitch as shown.

2. **Cheese (or Plasticine) Cutter.** Two round sticks, 3 in. to 4 in. long and ½ in. thick; copper wire about as thick as twine.

3. **Setting a Straight Line.** Stretch a chalked string between two given points. Lift the string and release. Chalk flicked off in a straight line.

4. **Flagstaff.** Bamboo garden stick. A hole is made at centre of baseboard and circle drawn with this hole as centre. Mark off the radius round circle. Put a nail at alternate points. Tie all strings to the flagstaff at *a*. Tighten the strings by means of *c*, a piece of wood with a hole drilled at each end as shown.

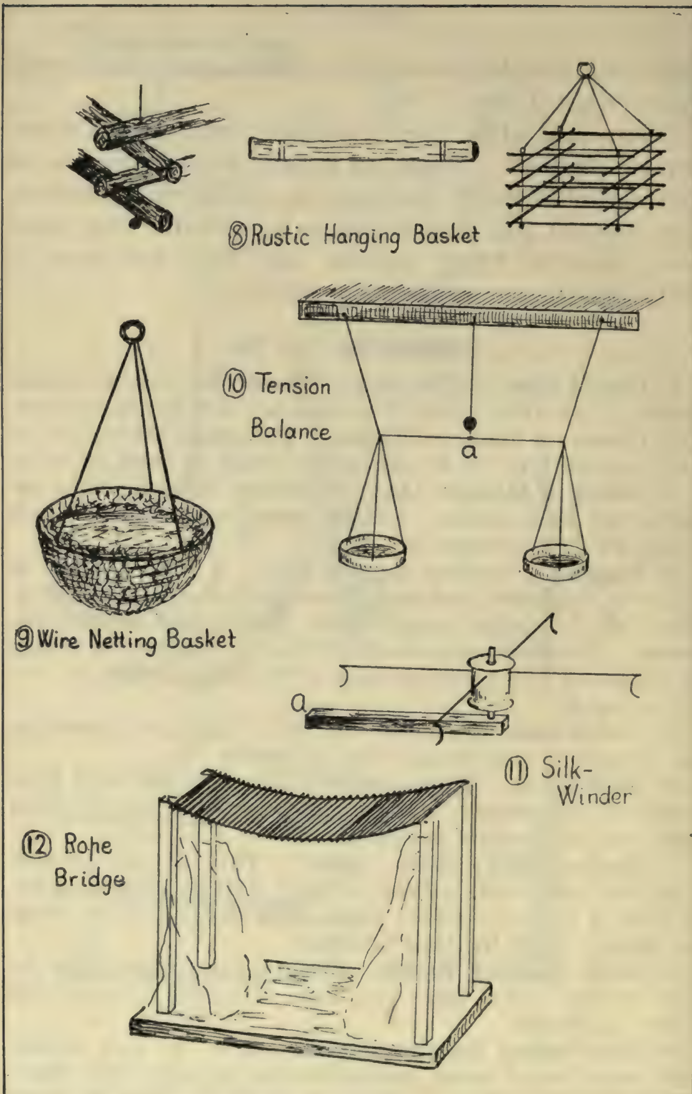
5. **Clothes Line.** Two posts and line. Fix as in 4, omitting one support in case of each post, as shown.

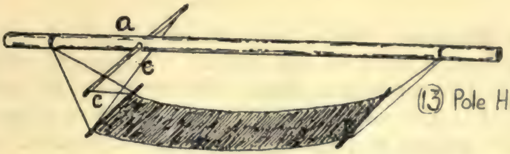
6. **Bookshelves.** Three boards of the same size, with holes drilled at the corners. Strings with large knots on the under side keep the boards in position.

7. **Obedient Ball.** Mark "poles." Drill an oblique hole from one pole—and a hole to meet it from opposite pole, or treat a reel as shown. These slide down a loose string, but stand still at the least tension.

8. **Rustic Hanging Basket.** Twenty twigs about 8 in. by ½ in. by ½ in. Drill holes 1 in. from each end. Thread and mount as shown.

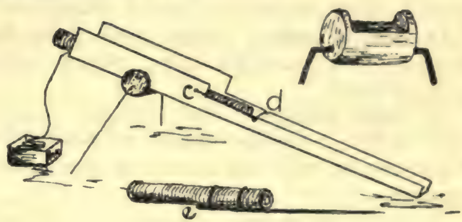
9. **Wire Netting Hanging Basket.** Press old wire netting into shape over a basin, and stiffen the top edge with wire; support by three wires or strings placed at equal distances apart.

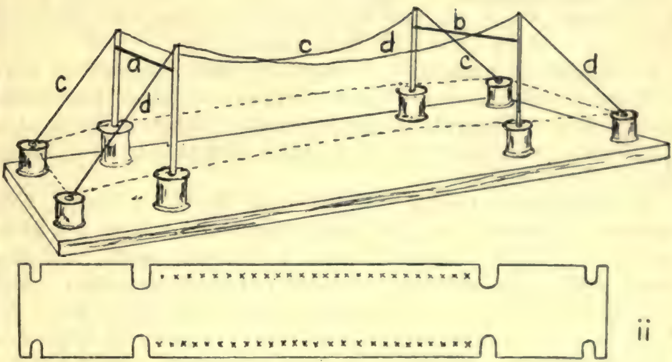

⑧ Rustic Hanging Basket
⑨ Wire Netting Basket
⑩ Tension Balance
a
a
⑪ Silk-Winder
⑫ Rope Bridge

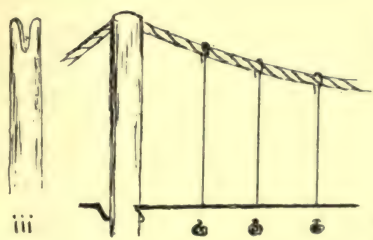


(13) Pole Hammock

(14) Rocket Apparatus







(15) Suspension Bridge

10. **Tension Balance.** Tie a loop at each end of about 4 ft. of string, and a knot in the middle. Hang the string by the loops on two nails in a shelf. Fix on the scale pans. When at rest, hang a plumbline immediately over knot *a*. Put 1 lb. weight in left pan and goods in the right until the knot is again in position under plumbline.

11. **Silk-Winder.** Cotton reel with four wires bent as shown. Use a nail for axle. Stand post upright, and screw to baseboard.

12. **Rope Bridge.** Four uprights (may be fixed in cotton reels as 15). A rope ladder with sticks packed very close. Use paper or starched muslin to represent rocks and hide the supports.

13. **Pole Hammock.** Bamboo (or other stick) with a hole at *a* through which passes a wood splint carrying the steadying cords *c*, *c*. Make hammock from muslin, etc.

14. **Rocket Apparatus.** Trough of card; stand—a cork with wire legs placed as shown; rocket—a coil of paper and match stick. The elastic to throw the rocket is fixed at *c*, and drawn back to notches at *d*. The lifeline is fixed to upper end of rocket stick *e*.

15. **Suspension Bridge.** Eight reels fixed to base; four uprights notched at top, as in (iii), and wired as at *a* and *b*; ropes *c c c*, *d d d*, pegged down to outside reels, hanging loosely with same amount of droop between uprights; roadway of card, as in (ii), with holes for supporting wires (or threads). (iv) shows wire looped over suspending rope and knotted below roadway.

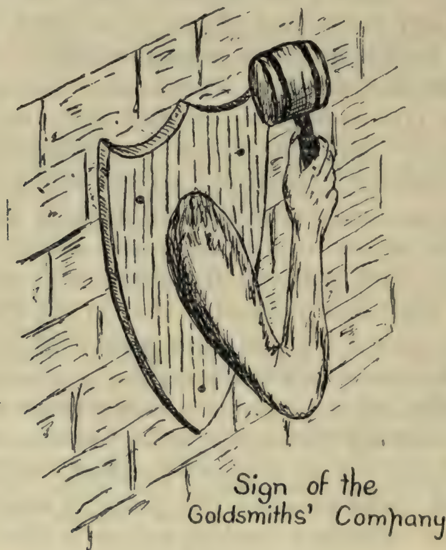
CHAPTER VI

Malleability and Plasticity

Malleability. London alone of all the great English cities still has its "Livery Companies" with their enormous wealth. They have come down to us from the middle ages when they were much more powerful in controlling their industries than they are to-day. There are some seventy-six city companies, divided into two groups—the "greater" and the "lesser." Among the greater is the Goldsmiths' Company, which still has a great deal to say in connection with all working in gold and silver. The sign is a naked arm and mallet, telling us one of the chief parts of the goldsmith's work—gold beating. You must remember that in the Middle Ages few people could read, and signs were used on places of business where we now employ names. Some substances, metals chiefly, are possessed of a very strange property—that of permitting themselves to be hammered out into very thin sheets. This property is called "malleability."

Gold Leaf. Gold possesses this property more than any other known substance, and it was early discovered by the metal workers of ancient civilizations. Gold leaf, as the beaten metal is called, was used by the Egyptians nearly four thousand years ago. Solomon's temple was largely decorated with gold leaf, and mummies and mummy cases from Egypt are ornamented with it. To get the thin leaves the gold is beaten out between two sheets of thick parchment, which are placed on a slab of marble. No one but the goldbeater himself knows how to get such evenly thin sheets. So thin can the gold be beaten, that 250,000 of them are needed, piled one on the

other, to make a thickness of one inch. This "leaf" is used for gilding picture frames and ornamenting outdoor metal work. The ball and cross on the top of St. Paul's Cathedral are covered with this thin gold leaf, and the gold is not tarnished by exposure, although it gets dirty in time from the smoke of London.



Metal Sheets. The "leadbeaters," like the goldbeaters, work their metal into sheets, which, however, are not so thin as gold leaf. The thinnest lead is called lead foil. It is used a great deal for lining tea-chests, to keep the tea from losing its strength and fragrance on the road from China or India to us. Lead sheet was much used in early days to cover the roofs of the great stone buildings. The roof of old St. Paul's was covered with sheet lead, and when the Cathedral burned in the Great Fire of London,

1666, the streets in the neighbourhood were covered with molten lead. Lead is still used for roofing purposes. It is easily hammered into artistic shapes, but is not used a great deal for ornamentation because it tarnishes so easily in the air.

Tin, too, is another malleable metal. Tinfoil is used for the wrapping of chocolates, as it keeps them from becoming damp and soft. When the tinfoil is taken off the chocolate, crackling of the tin can be heard. This crackling is called the "cry of the tin."

Copper is beaten out into foil and worked up with a hammer into all kinds of neat ornaments, but it blackens when exposed to the atmosphere.

Brittleness. If we attempted to beat a mass of a substance like glass into a sheet it would powder at the first blow of the hammer. Such a substance is said to be "brittle." There are many other substances in common use which are brittle and need careful handling. All glass ware and all china ware are brittle, as Hereward found when he played potter, and John Gilpin when he rode his race.

> "Then might all people well discern
> The bottles he had slung;
> A bottle swinging at each side
> As hath been said or sung.
>
> . . . .
>
> The bottles twain behind his back
> Were shattered at a blow."

Most of the iron railings in our streets are brittle, and although strong enough, in some ways, crack at once on getting a sharp knock. This cast iron, as it is called, is a very brittle substance. You must not think that the blacksmith could mend a cast iron railing in the same way as he could your broken iron hoop. The hoop is made of a different kind of iron—wrought iron—and this is

quite malleable when red hot. Not only can it be hammered out when hot but it can be pressed out, and shows no tendency to go back to its first shape. Substances of this kind which seem to have no elasticity and are easily worked into any desired shape, are called "plastic" substances. Plasticine, which you may have used in school, is one of them. Whatever shape you give it, it keeps. If it were not for this property of plasticity possessed by clay we should have no cheap crockery. Cups, saucers, jugs, chimney pots, bricks, tiles, pipes, are all made from plastic clay. You may remember when Robinson Crusoe was wrecked, how much trouble he had to get vessels to hold a liquid. "It would make the reader laugh at me to tell how many awkward ways I took to raise the paste. What odd, misshapen ugly things I made; how many fell in, and how many fell out, the clay being not stiff enough to stand its own weight; how many cracked by over violent heat from the sun, or how many fell to pieces with only removing. I could not make above two large ugly earthen things (I cannot call them jars) in about two months' labour."

The Potter. In India the potter is often seen travelling from village to village with his wheel. This he sets up anywhere, so that it spins horizontally. He gives it a spin and its inertia keeps it going; throws his plastic clay in the centre, and works up his pots into shape. Potters in our country—in the potteries of North Staffordshire—do the same kind of thing, but use a great deal more machinery to help them. Of course, it is the round articles that are made on the potter's wheel. The handles of cups and jugs are pressed into shape in a mould, the plastic clay easily taking and keeping the shape. The vessels are baked to harden them, and when hard they are no longer plastic, but become brittle.

Bricks. One of the largest industries in the S.E. part of our country is brickmaking. You have only to look at the miles of houses built of bricks to understand this. The clay runs in a thick bed right under London and comes up above ground a few miles out of town. On the outcrop—the place where it appears—bricks are pressed into shape by the million, and baked hard. From plastic clay they pass to brittle brick. Flower pots, red tiles, drain pipes, are made from plastic red clay, in other parts of the country, and a lot of plastic white clay for making china ware comes from Dorsetshire, Devonshire and Cornwall.

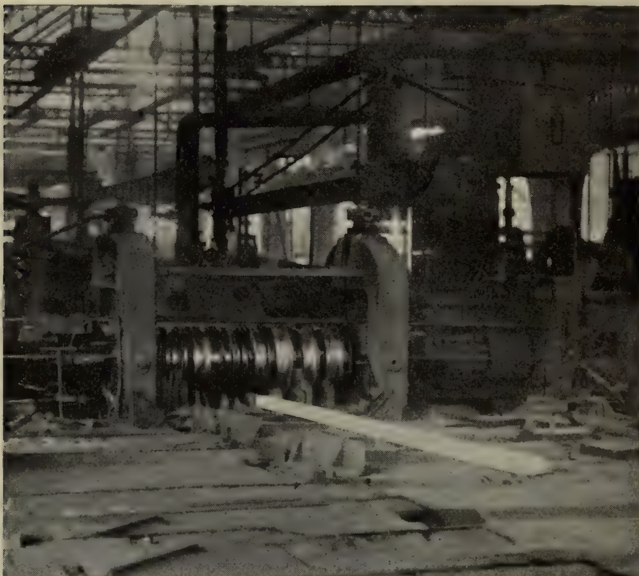
Rolling Mills. We said a little way back that hot wrought iron could be shaped as we pleased. In the North of England hot steel is pressed into all manner of shapes in great rolling mills. When the steel is in the plastic state it is rolled into sheets, made into railway lines, worked into blocks for placing in the sides of our great battleships, pressed into girders for bridges or shaped into keels and anchors for our great liners. The machinery of these mills is wonderfully strong.

Steel Rails. Thousands of miles of steel rails for trains and for trams are made every year. It is a wonderful sight to see the plastic bar go into a slot between two great rollers and come out almost a complete railway line on the opposite side of the roller. The machinery shapes it as easily as man can shape a piece of putty.

Sealing Wax. Another plastic substance that was much more important formerly than now is sealing wax. A stick of sealing wax, before it is heated, is really very brittle; but when softened it easily takes any shape we wish to give it, and keeps it on hardening. Shapes were pressed into the hot plastic wax by means of "seals."

Seals. The seals used in bygone days were of gold,

ivory, iron, and often very hard stone. Some of the earliest seals were about the size and appearance of small cotton reels with the rims cut off. The seal "picture" was cut on the surface of the "reel" and rolled on the soft wax, which was then allowed to harden. Seals are



By courtesy of the *Barrow Haematite Co.*

RAILWAY LINES IN THE MAKING
A redhot ingot passing through the rolling mill

generally flat nowadays. Magna Charta was sealed with white wax, for the red kind was not used in England until about 200 years later.

The Pope used lead for his seals, the lead being plastic enough to take the seal, and, not being brittle did not get damaged so easily as the wax seals. Lead seals have

been very much in use during the past few years, for the books of coupons for War Savings Certificates were done up in packets of 25 and sealed with a lead seal. The keeper of the King's Seal has a very responsible position.


Seals

Brick Books. Before the days of paper and parchment, plastic substances were used for book-writing. A brick or cylinder of clay was made, the writing traced on the surface while the clay was plastic and then the brick was baked. Some of these brick books from far off ages have been found near the Tower of Babel, and seem to have been first used by the Babylonians. We have specimens from these brick libraries in the British Museum.

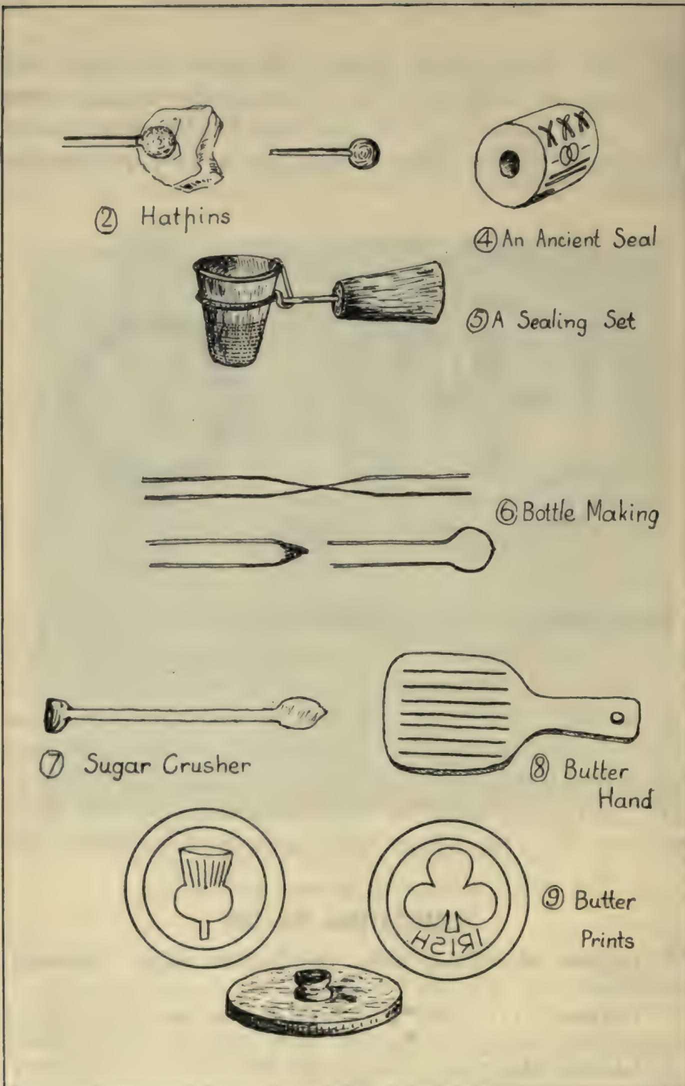
SOMETHING TO DO

1. **Impress of a Coin,** using (*a*) "silver paper" (tinfoil), (*b*) leadfoil.

2. **Hatpins.** Cover the black head of a hatpin with coloured sealing wax, giving any desired shape while hot and plastic.

3. **Earring Droppers.** Shape the wax round a thin wire

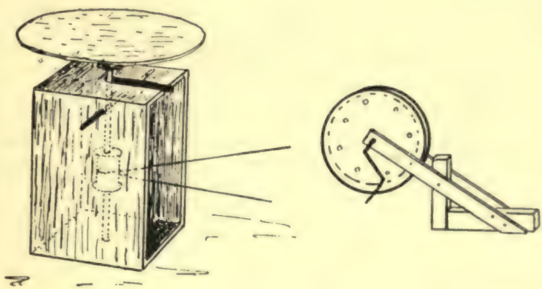
4. **An Ancient Seal.** Cotton reel with rims removed. Burn out a pattern and soak the reel in oil. Roll on axle


② Hatpins
④ An Ancient Seal
⑤ A Sealing Set
⑥ Bottle Making
⑦ Sugar Crusher
⑧ Butter Hand
⑨ Butter Prints
IRISH

through hole, over plasticine or hot wax, to get an impress.

5. **A Sealing Set.** Thimble on hairpin in cork handle; candle; seal. Melt a pellet of wax in ladle, put on envelope, and impress with seal.

6. **Bottle-making.** Draw a piece of glass tube by heating in a bunsen flame. Seal the end in the flame, and continue heating and turning until a soft mass is formed at the closed end; blow gently at the open end.



(10) Potter's Wheel

7. **A Sugar Crusher.** Take 4 in. of glass rod and melt one end *slowly*, and press flat on charcoal. When cool, melt the other end and press flat between two pieces of charcoal.

8. **A Pair of Butter Hands.** Cut thin boards to shape. Burn out grooves as shown with hot wire.

9. **Butter Prints.** Use squares or circles of wood. Burn pattern with hot wire. Impress on plasticine.

10. **Potter's Wheel.** Axle (penholder) to which are firmly fixed two reels. Wooden or card disc fitted to top reel by

nails or screws. Chalk box slit in top wide enough for axle, and a hole on bottom arranged for the axle to keep it upright, A knitting needle keeps axle in place. Multiplying wheels (*a*) cotton reel on axle ; (*b*) three discs of card fixed with paper fasteners, a square hole at centre, and a square axle tapered round to pass out of supports. Supports for driving wheel as shown (or see Quern, on p. 13).

CHAPTER VII

Adhesion

SOME substances have great tenacity. This property is due to the power that the particles have of holding one to the other. This power is called the "force of cohesion." When we stick a stamp on an envelope the two hold together but for quite a different reason. The gum sticks to the envelope and also to the stamp and so holds them one to the other. It is not the particles of the stamp paper and the particles of the envelope paper cohering; they are separated by a layer of gum which sticks to each. When one substance quite different from another sticks to it, we say the two substances "adhere," and are held together by the force of adhesion. Substances that adhere to others in this way are called adhesives. Quite a large number are in everyday use.

Adhesion. Some adhesives are made from animal material, such as glue; but others are obtained from plant material like gum and starch. Glues were made in very early times and in the ruins of Thebes, an ancient town on the Nile, we find a carving showing a workman using a glue brush. He is getting a slab of wood ready for the veneer, or thin sheet of a better kind of wood, to be fixed to the front of a poorer kind. This is constantly done to-day; indeed, most furniture is veneered.

Other adhesives are sticking plaster and fly papers. Fly papers are made on the same plan as the spider's web. If we examine under a magnifying glass a thread of a spider's web we find all along it tiny beads of sticky fluid—the adhesive that captures the fly. The sticky substance for fly papers is made by boiling together

linseed oil and resin. This is then spread on paper ribbons and hung up to catch the flies. You would not think that such material could be used for catching larger vermin; yet birds and monkeys—and even tigers—are taken by using adhesives.

Bird catchers spread "birdlime"—a very gluey material—on the branches of trees. Birds settle to roost for the night and find themselves glued to the branches by morning, when the bird catcher comes to take them away. When the Swiss Family Robinson had their plantation repeatedly destroyed by monkeys, they caught the monkeys by using birdlime. "Everything was plentifully besmeared with birdlime, and basins of the mixture were set in all directions strewn with rice, maize, and other dainties for bait. . . . . Very early in the morning we heard a very confused noise. As they rambled over the place all in turn became besmeared with birdlime, on head, paws, back and breast. Some sat down with ludicrous gestures and tried to clean themselves, others again endeavoured to help each other, and stuck together—the more they pulled and tugged and kicked the worse they became. One old fellow who had found a calabash filled with wine eagerly drank it, and was fitted with a mask, for the shell stuck to his forehead and his whiskers, and of course covered his eyes." In this predicament the monkeys were easily killed.

Traps. In India some 1,000 people are killed every year by tigers and every means is taken to destroy the animals. One strange way is to cover a large number of leaves with an adhesive like birdlime, and spread the leaves on the ground round a tempting bait. The tiger puts his paw on a sticky leaf. He wipes it off by rubbing his paw on his head, so fixing the leaf there. He puts his paw down and another leaf clings to it. He becomes

enraged, dances among the leaves and so obtains a further share. He rolls on the ground to get rid of them and gets more still and in this state is an easy victim. Simple means often achieve great ends.

There are many insects that attack our fruit trees causing damage to the extent of thousands of pounds each year. The larvae climb the stems of the trees. To stop them the fruit grower places "grease bands" round his trees. The grease captures the larvae as they climb. After a time the bands can be taken off and burned, and the larvae are destroyed in this way.


Grease Bands on a Fruit Tree

Catching moths and insects with treacle is an old trick of collectors. The treacle band is put on the trees at night and the collector visits them next morning to see what the night's catch has been.

Deep Sea Sounding. In the early way of taking deep sea soundings the bottom of the sounding rod was hollow and filled with tallow. When the weight struck the bed of the ocean some of the "floor" stuck to the tallow and was brought up for examination. You may remember, too, the story of the "Forty Thieves" from the Arabian Nights. Cassim's wife, curious to know what her sister-in-law wanted the measure for, fixed a small piece of suet in the bottom of it. The suet brought back embedded in it a piece of gold, and so began all the troubles. The fat in these cases was used as an adhesive.

Gums and glues are so well known and in such constant daily use as adhesives that nothing need be said here about them.

Distempers. Extensive use has been made in the last few years of "distempers" and "washes" for walls. They adhere to the brick and plaster, and as they can be bought in all tints are highly decorative. There was a time when they were put on always with a brush. But some few years ago it became necessary to get an exhibition building ready in a very short time. An army of men with brushes would not have done the work quickly enough. Then came an inventor with a machine for blowing the liquid on to the walls, where it remained. Since then these spraying machines have been used on a very large scale for decorating with both distempers and paints. We have even gone further quite recently, and can now build houses with spraying machines. A house framework is put up and a cement mixture is blown on to the frame where it adheres. One or two men with a spraying machine can *blow up* a house in very little time. It is much quicker than fixing bricks together with mortar.

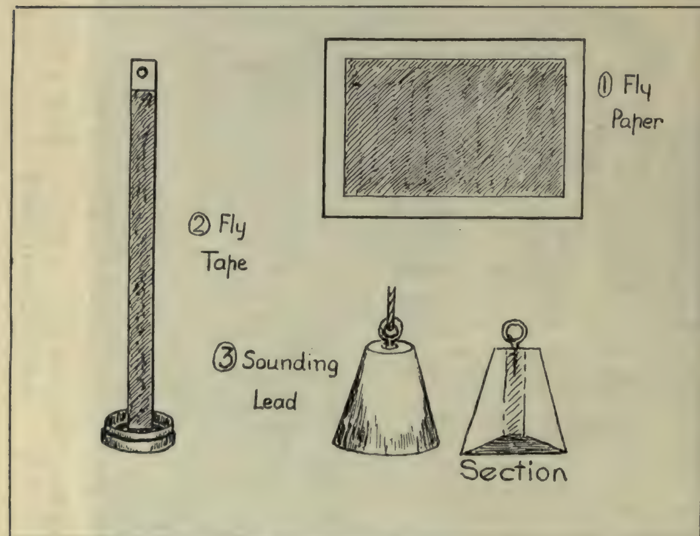
Animals use Adhesives. Adhesives play an important part in the life of certain animals. In the south of Europe is a small lizard called the gheko. He lives in houses, and makes himself useful by eating flies, spiders, and other insects. As evening draws on he may be seen running rapidly up walls and along ceilings. He seems to defy gravitation, but when we look at his feet we find them broad and with a kind of fringe to each toe. From this fringe a sticky substance comes that holds him to the wall or ceiling.

Another animal using an adhesive—this time to secure its prey—is the chameleon. He watches a fly, and when it is near enough out goes five or six inches of tongue, the tip of which is very sticky. He never misses, and his tongue goes back with lightning-like speed carrying the fly to his throat.

HOUSES BEING "BLOWN UP" WITH A "CEMENT GUN" AT SOUTHEND-ON-SEA

The cement is blown cn to the expanded metal attached to the framework of the house

The great ant-bear lives in South America. He is six feet long, and lives on nothing but ants. His powerful claws soon tear a hole in an ant-hill. Then the ants rush out, and the ant bear puts his tongue on the ground in their midst. The ants rush to attack it, and thousands stick to it, for it is covered with a very sticky substance



indeed. When his tongue is sufficiently covered to his liking, he draws it in and swallows the catch.

Dextrin. I suppose there are few who have not at some time stuck a stamp on an envelope. At the back of the stamp is an adhesive called dextrin. It is made from starch. For many years the secret of its manufacture was kept in the hands of two brothers, who worked by themselves in a house quite away from all other dwellings. They used only the top rooms. All Government stamps

were passed through their hands in order to have the adhesive put on. The secret was discovered by a watcher climbing a tree and noting through the window all that was going on within. Like many another great secret, the process was very simple. The starch was merely heated to a certain temperature and the dextrin was made.

SOMETHING TO DO

1. **Fly Paper.** Spread treacle thinly over stiff paper to within 1 in. of edge.

2. **Fly Tape.** Paper ribbon, 2 in. wide; cardboard box with a lid. Cut a slit in the bottom of the box, draw 1 in. of ribbon through, and gum to the box. Place lid over the *bottom* of the box. Cover ribbon with adhesive (treacle).

3. **Sounding Lead** for use in shallow water. Cut a cotton reel down as shown, put a wooden plug into the hole and fix a screw eye into the plug. Weight by wrapping round with iron wire till the sounder sinks easily. Put tallow in the hollow bottom, as shown in the section.

CHAPTER VIII

Some Hard and Some Soft Substances

There are innumerable hard substances and soft substances as everyone knows. Some of them are of great importance in everyday life.

> "Two vast and trunkless legs of stone
> Stand in the desert. Near them on the sand
> Half sunk, a shattered visage lies, whose frown
> And wrinkled lip, and sneer of cold command
> Tell that its sculptor well those passions read
> Which yet survive, stamped on these lifeless things."

Ozymandias of Egypt, about whom the poet Shelley wrote these lines, lived ages ago. We know very little about him—except that he was a boaster. He set up a mighty image of himself, to last for all time. It is a ruin, but, in spite of the ages through which the rock figure has been cut by the sand in the desert sandstorms, we are still able to see something of his features. This proves to us that the rock of which the figure was made was extremely hard.

Granite. Granite is one of the very hardest stones we have. It is made up of three distinct rocks well mixed; one black and shiny, another hard and white, and a third hard, pink or grey, that give us red or grey granite. The white rock known as quartz is the same material as sand, but the sand consists of very tiny pieces.

Because of its hardness, sand, like granite, has many uses. It has been used for ages by stone workers to help them cut their stone. It is used nowadays for making ground glass. The sand is blown with great force against the glass, and so hard is the sand that it cuts the glass where it strikes it. The appearance of ground glass is

due to these millions of little cuts. The sandblast is used, too, in our iron and steel works for cleaning and brightening the metal, and more recently for sharpening tools.

On account of its hardness, granite and similar rocks have been used for making roads. Sometimes the granite is put down in small pieces as big as a man's fist, and ground in by the road roller. At others it is put down in blocks about as large as a brick, making the road look like a wall laid flat. Such roads stand a tremendous amount of heavy traffic.

Granite is used for building our lighthouses and harbours, our bridges and our greatest buildings. The pavements in our streets are often of granite. It is first ground to powder, and then mixed with an adhesive and made up into slabs. You will sometimes see the name "Shap Granite," or "Threlkeld Granite," marked in the pavement in brass letters. You might discover what that means.

Sandstone. Very often we find our pavements made of large oblong pieces of a yellowish stone called York flag. This is sandstone—grains of sand with an adhesive binding the grains together. It is wonderfully hard and lasts a long time. Sandstones of different kinds are used in many ways. Grindstones for sharpening knives and grinding axes for timber cutting are made of sandstone. Hundreds of such sandstone wheels are used throughout the country. They are often to be seen standing at the side of railway sheds, so that the platelayers may sharpen their axes. They are used in the cutlery districts round Sheffield. "Millstone grit," from which the grindstones used in these districts are made, is found in the quarries near by and had a great deal to do with locating the cutlery industry at Sheffield.

The hardest artificial substance we know is carborundum.

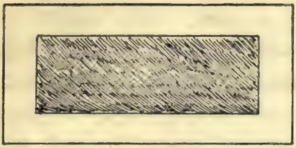
The diamond is extremely hard. We say "diamond cut diamond" because the chips and dust of diamonds are used in grinding and polishing diamonds. Diamond drills are used for boring holes in the hardest rocks, especially quartz in which gold is found. Of course, the best diamonds are not used. Poor samples are fixed in a ring so that they just protrude a little. The ring is at the end of a rod. This is twisted round very rapidly by machinery and soon wears a hole in the hardest rock. Mining in hard rock would be very slow if it were not for the diamond drill.

During the Great War many people who worked on big lathes, realized the hardness of some kinds of steel. We can use steel to cut steel. The hardest steel will take shavings from a softer steel just as a plane takes shavings from wood, and it is not easily blunted in the process. Chisels and files are made of steel and are specially hardened.

Some of the soft substances much used in everyday life have already been spoken about—clay for example. Many rocks, although hard if you fall against them, are soft in that they easily rub or crumble away. Chalk rocks are soft as rocks. We have whole ranges of chalk hills in our country and the chalk is easily worked. The farmer throws it on his land to improve the soil.

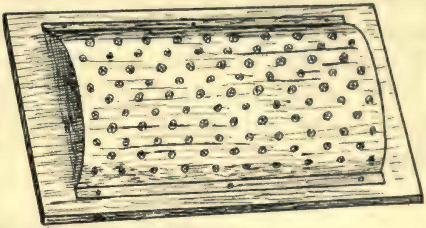
Sand is a soft rock if loose, but the grains are very hard indeed and when they are held together they form a very hard substance known as sandstone, which we have already seen is very useful on account of its hardness.

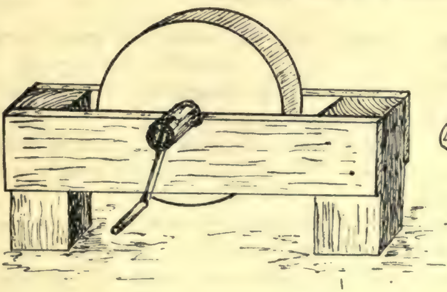
Wood. In some districts our streets are paved with wood blocks. This wood comes mainly from Australia. It is called Jarrah or Australian red wood. The tree



① Pencil Sharpener

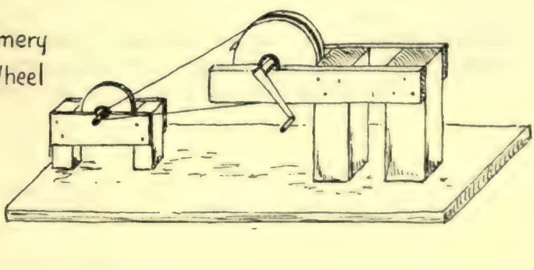
③ Bread Crumbler





④ Grindstone

⑤ Emery Wheel



from which it comes grows as high as St. Paul's (400 feet). This wood lasts quite a long time under heavy traffic and as you know makes a quiet road. Millions of blocks are used every year. Our hardest wood is oak, but our oak forests are not nearly so great as they used to be when England depended upon the oak for her warships. Many hard woods are brought into this country for furniture making. Walnut, ebony, boxwood, oak, mahogany, come in by the shipload.

Softer woods like deal are much used for making floors, sheds, boxes and packing cases and for general building purposes.

SOMETHING TO DO

1. **Pencil Sharpener.** Small slab of wood or card with sandpaper centre.

2. **Abrasives.** Collect samples of abrasives, e.g. emery cloth, sandpaper, brick dust, sand, pumice, etc.

3. **Bread Crumbler.** Take a piece of clean tin, punch holes as shown, and bend to shape. Fix to board with rough side of punchings outwards.

4. **Grindstone.** Wheel is a section of large cotton reel with sandpaper glued round edge; card or wood for sides and wooden uprights. Axle, a penholder with slit at end. Flatten iron wire at point where put into slit, and twist round axle to grip.

5. **Emery Wheel.** As above (smaller), but wooden sides and staple to keep axle in position. Driving wheel made as for potter's wheel, or as shown, a wooden disc with groove.

CHAPTER IX

Friction

It has been a dream in the life of many men to invent a machine that should go for ever. None has succeeded. Probably none ever will succeed unless and until we can find out how to stop one part of the machine from rubbing against another part when moving. This rubbing of one thing against another, called *friction*, plays a tremendous part in our daily lives. Friction exists only when things move: it always tends to stop the motion of the things pressing one on the other, no matter which way we want to move. That is why we cannot get perpetual motion at present.

Perpetual Motion. Some years ago, men set a top spinning and found that it spun for about half an hour and then stopped. It was rubbing against the air and its peg was rubbing against the surface on which it was spinning. They made the peg sharper, and set the top spinning again on the hardest and smoothest surface they could obtain. Then they took away the air, so that there was only the tiny peg rubbing against the hard plate. It went on spinning for days, but in the end friction—the rubbing of the peg against the plate—made it stop spinning. You will remember that Newton said things once set moving would keep moving, if there was no interfering force to stop them. But friction always impedes motion and so moving things do not move for ever.

Top spinning in a vacuum

Sliding and Rolling Friction. There are two kinds of friction. One, called *sliding* friction, occurs when one substance slides over another. The other is called *rolling* friction. When a car wheel revolves, different points of the rim are in contact with the road at each moment. The wheel rolls and seems to grip the road. This apparent gripping shows there is rolling friction or rubbing between the road and the wheel. Rolling friction is not nearly such a hindrance to movement as sliding friction. For this reason we prefer wheels on our carts to runners such as are fixed to sledges. A magnifying glass reveals minute " hills and dales " on every surface, so that when one surface slides on another the hills of one fit into the dales of the other, and so movement is resisted. In rolling, these hills and dales do not always slide one on the other, for in most cases they do not coincide or they are *lifted apart.* One of the first things we notice when we rub things together is that they get hot—the harder we rub the hotter they get. Sliding friction is one of the chief means adopted by savage races for obtaining fire.

Fire Stick. The Australian aboriginal takes a hard stick and points it at one end. He then makes a groove in a softer piece, sprinkles it with dry grass dust, and rubs the stick in the groove as hard and as fast as he can. The wood gets so hot that the grass dust smoulders and then he blows gently till it flames. Many—very many—white men have tried this, but very few have ever succeeded in obtaining fire.

Mammoth Caves of Kentucky. Among the marvels of the world are the mammoth caves of Kentucky, which penetrate for six miles underground according to present knowledge—and no one knows how much further still. Many strange and wonderful caves and deep shafts

are met there. One of these deep shafts is called the Maelstrom Shaft. For long after its discovery no man would venture into its roaring depths. At last a boy, William Prentice, decided he would go down. A heavy wooden beam was placed across the top of the shaft. Five or six men lowered him and his lantern into the shaft. It was very deep but he reached and explored the bottom. During the last stage of his journey upward, as the men pulled the rope over the beam, the rope suddenly caught fire. Prentice was hanging by the slender rope set on fire by the friction, and the base of the shaft was 175 feet below him. One of the men dashed the water from his water bottle on the flaming rope and luckily put out the flames. This saved William's life. If they had drawn the rope over a wheel the accident would not have happened.

Sliding friction, so useful to the Australian, was quite the opposite to William Prentice. We employ friction usefully every time we strike a match. Matches, however, have not been in use very many years. You may have heard smokers, quite strangers to each other, say, "Oblige me with a light, please." That comes down from days when lights were not easily obtained, and in those days when anyone had a light he was willing to share it with any neighbour. In those times a flint and steel were used.

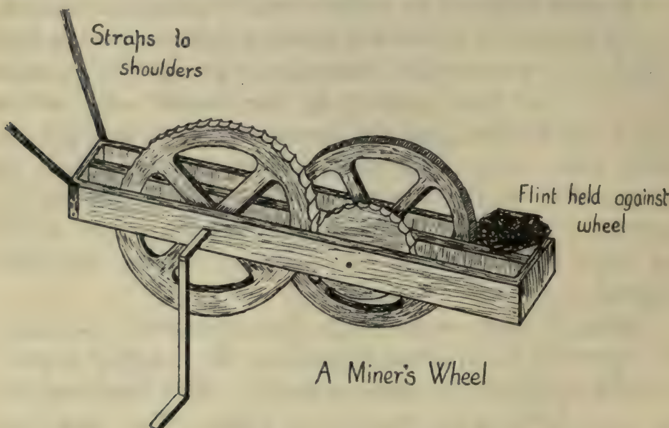
Flint and Steel. A rough steel was struck against a piece of flint, and the sparks caused by the friction fell upon charred rag or tinder which caught fire on blowing it gently.

Flint Lock

Many people know that in coal mines a safety lamp is used. But coal was mined years and years before the

safety lamp was invented. How did the miners see to work in the mines then? Explosion would follow the use of a candle or lamp with a naked flame.

Miner's Wheel. Friction helped in this case, and the miner's wheel—a wheel with an edge like a file—was turned round quickly and a piece of flint pressed against



A Miner's Wheel

it. A shower of sparks came—and that was all the light the miners had. The sparks were not so liable to set the mine gases on fire or to cause explosion as a constant flame would be. You have most likely seen a pipe lighter worked with a tiny wheel with a file edge and a piece of metal, known as a "flint," because it acts as flint stone does. This also depends for its working upon friction. When muskets, as old-fashioned guns were called, first came into use, they were fired by means of a slow match. Later a great improvement was made when the flint lock was invented. A flint was fixed to the trigger, and when the trigger was pulled the flint struck against a file and produced sparks which set the gunpowder behind the bullet alight.

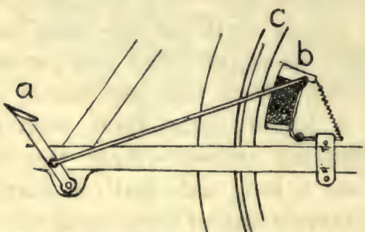
Stone Saw. Perhaps you have a stoneyard near you. If you have seen the sawyer at work you will have noticed his saw which has no teeth. It is so heavy that it is held up by ropes. The sawyer at intervals puts sand alongside the saw, and washes it into the crack cut by the saw. The friction of the sand and the saw cuts the stone.

Friction, too, is used to cut stone from quarries into huge blocks. A long endless hard steel wire passes over two large wheels. It is made to move very quickly indeed, and with the help of sand and water cuts its way through the stone. As it gets very hot from the friction, it has to have a cold bath on the way back before rubbing against the rock again. For this purpose, the larger one of the two big wheels dips into water.

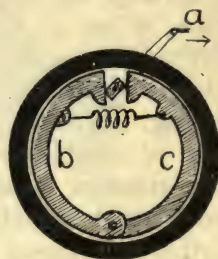
Belting. Perhaps, in a factory, you have seen the wheels of machinery whirring round. Near the roof of the machine room runs a long axle with a number of small wheels upon it. Over many of these small wheels a leather belt passes to the machines below. The axle above is turned by the engines, and the leather belt conveys the motion, by friction, to the machines below. A friction belt doing the same kind of work, may be seen at the side of some motor bicycles, or on a treadle sewing machine.

Belt Hammer. A belt hammer is a useful application of rolling friction. A block of iron, far too heavy for a workman to lift, is attached to a leather belt. This belt passes over a shaft turning slowly above his head. When he wants to lift the hammer, he pulls the belt against the shaft and the friction between the rolling shaft and belt lifts the hammer head. When it is high enough to give a blow as hard as the workman needs, he loosens the belt which leaves the wheel overhead and the weight drops down.

Brakes. Every traveller has probably read the notice in a railway carriage: "£5 penalty for improper use." It is placed near a chain running through the carriage. If the chain is pulled, the train comes to a standstill very quickly, for the brakes are applied at once. The brakes are iron blocks that, when needed, are pressed against the wheels, and by increasing the friction, finally stop the wheels from turning. Brakes are used on every wheeled conveyance. All act upon the same principle of increasing friction.



Rim Brake – Pedal a is pushed down and draws brake b against rim C



Internal Expanding Brake a is moved and presses b and C outwards.

Pit Head Brake. A brake is used at the pit head, to stop the engine that winds the rope which brings the miners or the minerals from below. In America, some years back, when coal mines were being started in Pennsylvania, a terrible accident happened. The brakesman in charge of the winding gear had his attention called away for a second, and failed to notice the red tape fixed on the rope to give warning to apply the brake. The engine went on winding up the rope. The cage crashed up to the top of the shaft, the rope snapped and the cage fell back to the bottom of the shaft. All the occupants were killed. The brakesman was, of course,

dismissed, but it had such an effect upon him that he spent his days at the winding shed, watching the cage come and go. One day a fire broke out in the mine and warning came for the cage to be hauled up at once. The old brakesman sprang to his place at the wheel before the new man could stop him, and the new man dare not interfere for fear of causing a second disaster. But the old brakesman applied the brake and stopped the overloaded car correctly—and the men who came up were the only men saved from the fire.

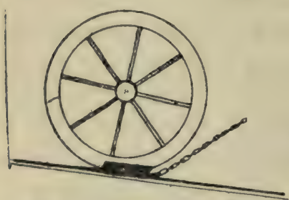
The Shoe or Skidpan. Brakes on a char-à-banc are helped, when the char-à-banc is going down hill, by means of a *shoe*. The shoe is a piece of iron bent at the sides so as to fit the outside of the rim of the wheel. It is slipped under the front of the wheel and held in position by a chain. The wheel cannot turn when the shoe is applied and the rolling friction of the wheel is changed into the sliding friction of the shoe which acts as a very powerful brake. Unfortunately the shoe damages the road very much, as you would see if you looked at the road after a heavy char-à-banc had gone down hill with its shoe on.

Horse Shoes. Has it ever occurred to you that a horse's shoe has to be made into a brake for the horse? This is especially so in winter, when a good carman takes his horses to the blacksmith, to get the shoes *sharped* or *roughed*, so that the horse may be better able to get a grip on the road by the friction between his foot and the road being increased.

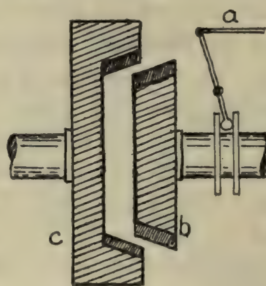
Emery Wheels. Emery and carborundum are very hard substances indeed. They are made up into wheels and are made to revolve at such a great speed that they work at the same rate as a powerful file, moving at a mile a minute. They are employed to grind steel knives

and scissors and other sharp steel instruments. You have seen the mower sharpening his scythe to cut grass. He uses friction and grinds away the steel with a sandstone in much the same way as a butcher sharpens his knives on his steel—which is a kind of file.

Friction Clutch. One other use to which friction has been much put in engineering during the past few years is to be found in the *friction clutch* of motor-cars. The engine of a car is often kept running yet the car stands



Shoe on Wheel - rolling friction becomes sliding friction



Friction Clutch Lever a pushes b into C and the two wheels act as one

still! When the driver wants to start the car he "lets in the clutch." The clutch consists of two wheels which can be separated from each other a little. One is turned by the engine. The other is attached to the road wheels. When separated the engine can work, but the car stands still. After "letting in the clutch," which amounts to squeezing the two wheels together, the friction makes them work as though they were one, and so the engine turns the road wheels. The friction clutch is often used in a factory for connecting and disconnecting the machinery with the engine. This saves stopping the engine in order to stop one machine. The greater the friction in the friction clutch the better the car works. Yet we spend a great deal of time in trying to get rid of friction in other parts of motor-cars and machinery!

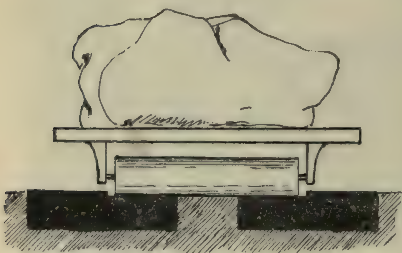
Ball Bearings. One of the most satisfactory ways of getting rid of friction is by making ball bearings support the wheel axle. Then the axle rests only on a few points

By courtesy of *S.K.F. Co., Kingsway, London*

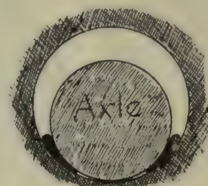
BALL BEARINGS IN A RAILWAY WAGON AXLE BOX

of the surface of the balls and if these are kept well oiled there is very little friction indeed. Ball bearings are a modern invention and could only be made when we had discovered how to make very hard steel. Sometimes, instead of balls, rollers are used in very heavy machinery.

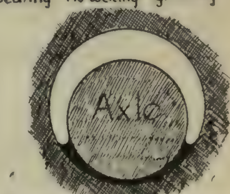
Tram Lines and Train Lines. Friction has been such a constant source of hindrance to engineers of all kinds, that much time and thought has been given to finding ways of lessening it. To-day we are so used to seeing tram lines and train lines that we take their existence for granted as though they had been there for all time. But it is not a great length of time since they were invented. The first lines were not at all like those in use now.



Front view of truck on rollers – "tramway lines" are shown black



Bearing- No wetting - grinding

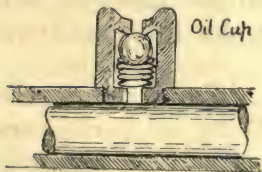


Bearing- wetting - no grinding

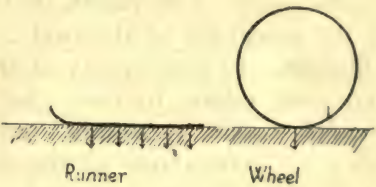
Usually they were broad smooth slabs of stone placed in lines and far enough apart to take the wheels of the carts or trolleys. On Dartmoor are still to be seen the remains of such a tram line, on which blocks of granite were brought down for shipment for harbour works in other parts of the country. These slabs were much smoother than the rest of the road and so lessened friction. It is from such arrangements, either of wooden planks, slabs of stone, and flat pieces of iron used to lessen road friction, that the modern tram line and railway line have come. The great speed of our railway trains is due

to the smoothness of the lines giving so small an amount of friction between the track and the train.

Lubrication. Many boys, anxious to become engineers, undertake work in the great engineering sheds, and are first set to work to "oil the engine." For every engine, every carriage, every truck, has the friction of the working parts lessened as much as possible by oiling. The oil is put into little cups, and from these trickles slowly down to where the metal parts are rubbing one on the other. The oil works its way between the rubbing



Spout of oil can presses ball and oil fills cup Spring replaces ball



surfaces and completely separates them. A thin film of oil—it may be but $\frac{1}{10000}$ of an inch thick—keeps the metals apart. It makes its way between the metals by capillary attraction. Axles are sometimes oiled with solid grease. Grease boxes are attached to all railway waggons—one to each wheel. Some few years ago on one of our electric railways a new engine was being set to work to take the place of three smaller ones. When it had been going for a short time and the great fly-wheel, weighing very many tons, was spinning at a high speed, something went wrong with the oiling arrangements, and the axle began to get red hot owing to the great amount of friction. The engineers threw buckets of oil on the axle. The oil was at once turned into dense smoke by the heat. By degrees they managed to slow down the engine.

Lubrication is necessary to ensure easy running, and when oil is used where there was friction between solids it is replaced by friction between a liquid and a solid, which is a much less serious matter.

Some parts of machinery, however, cannot be lubricated with oil. This is especially the case where wooden parts slide one on another. The oil would soak into the pores and make the wood swell. To get over this difficulty black lead or graphite is used. It is dry but slippery. Occasionally it is used, too, for lubricating chains of bicycles and heavy motors. When machinery at work becomes short of lubricant, its troubles are made known by the squeaking of the parts.

Sledges. In most parts of the world carts are used employing rolling friction; but there are parts where wheeled traffic is almost unknown. The Laplander and other inhabitants of the frozen North use sledges fitted with runners, instead of wheels. The wheels presenting only a small surface to the snow would sink in, while the runners lying flat on the snow do not sink so easily. In the case of the wheel all the weight is exerted at one point, in that of the runner it is spread over the broader surface; and owing to the slippery nature of the surface over which the sledge travels there is little friction.

Snow Skates. The Laplander himself has snow skates much like the runners of his sledge. One is about as long as he is tall, the other a little shorter. The "skiders" are made of fir wood covered with young reindeer's skin with the hair pointing backwards. This offers resistance to backward motion, as the bristles tend to stick into the snow, while they lie smooth as the skater moves forward over the frozen surface.

Ice. During the Russo-Japanese war, in 1905, the

Japs were about to attack a great Russian earthwork. It was in the depth of winter. The Russians, informed by their spies of what was about to happen, flooded the front slope of the trenches with hot water. This soon changed into smooth ice, and, especially as the ground was sloping, afforded no frictional grip to the feet of the Japs, who suffered very heavy losses indeed in the attack.

Ice is the nearest approach we have, on a large scale, to a substance that will allow things to move over it without friction. It is turned to use in countries where rivers and waterways become frozen in winter. The Dutch use their canals as roads along which they can skate at a high speed. They actually beat the Spaniards once by their ability to skate, as you may read in Mr. G. A. Henty's book, *By Pike and Dyke.* The Russians use their frozen rivers as highways for sledges in winter. The trappers of the great North West often go for miles along frozen rivers and lakes to set their traps, skating distances they could never cover in the time any other way. Many stories are told of trappers being chased by wolves and saving themselves by dodging, for the wolves slide and cannot turn on the slippery ice as the man on skates can.

Ice Yachts. On the great lakes of Canada ice yachts are used when the lakes are frozen. They are made of a **T** shaped frame with a large skate at the end of each arm, and another as a rudder at the end of the stem. A mast and sail are fitted up and the yacht can travel before the wind at an enormous speed, for friction between the runners and the ice is very small indeed.

Shooting Stars. Every twenty-four hours about a million or more shooting stars come to our earth. They are of all sizes, but generally reach the surface as dust ;

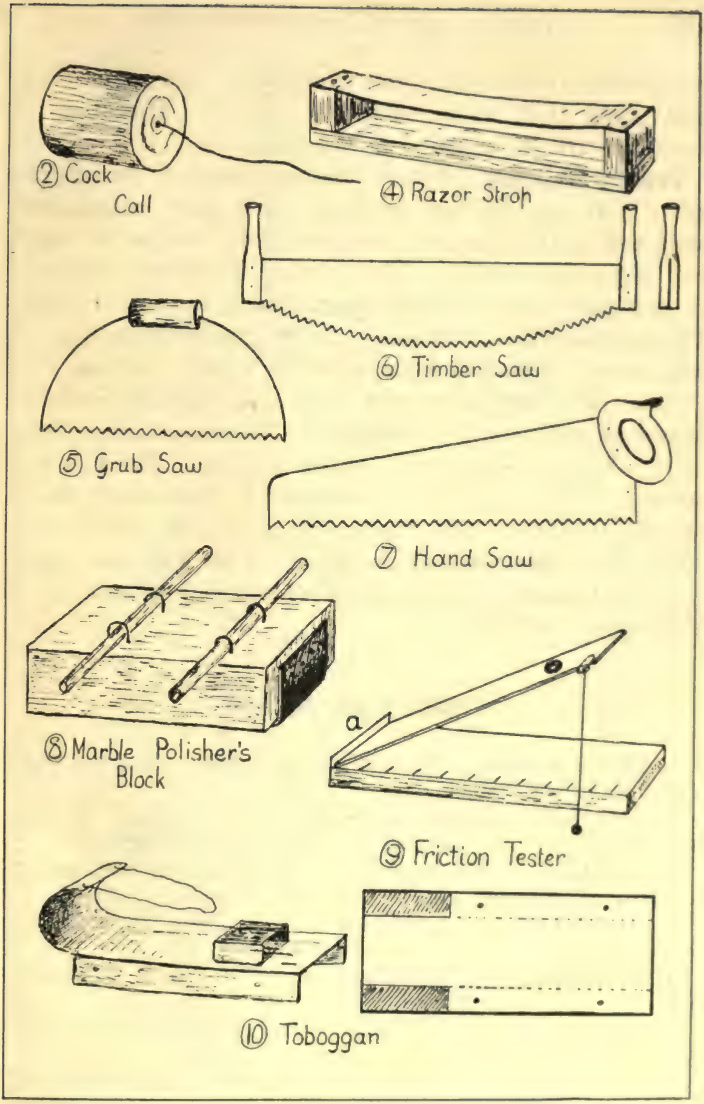
for, as they travel at some 700 miles a minute, on reaching the upper air the friction is so great that they become white hot. They burn away or the heat makes them

By permission of the Government of Ontario

AN ICE YACHT ON LAKE ONTARIO

A speed of 60–80 miles an hour is easily reached.

burst fifty miles up in the air. At night time we can see the white streak of light across the sky; during the day the sun's light is too strong to allow us to see them. Some

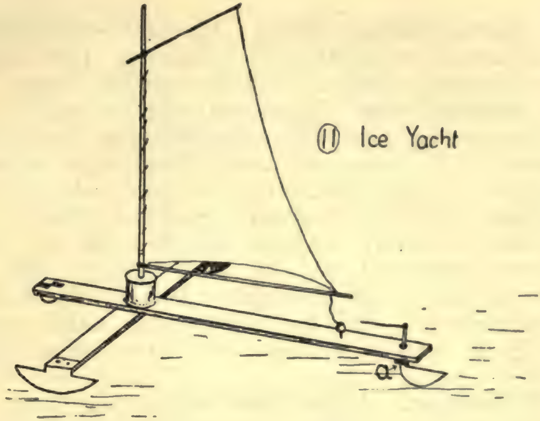

② Cock Call
④ Razor Strop
⑥ Timber Saw
⑤ Grub Saw
⑦ Hand Saw
⑧ Marble Polisher's Block
a
⑨ Friction Tester
⑩ Toboggan

have been so large that the friction has not worn them away, and they have reached the earth. Hundreds of examples are to be found in our museums.

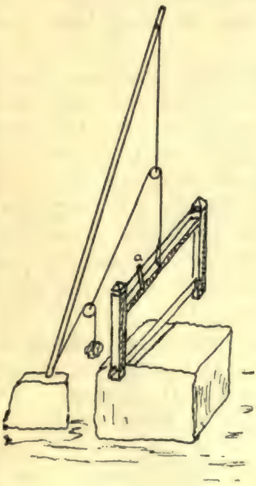
Testing Friction. Before leaving friction we should learn that the friction between two given substances need not be the same in quantity as the friction between two other substances. The friction between steel and brass is not equal to the friction between wood and stone. The friction of iron on oak is much greater than that of oak on oak. Iron on brass gives very little friction, and so you will often see iron or steel axles running in brass or gun metal sockets or bearings. It is easy to test these facts. Take a board and a sheet of glass. Put a penny on each, and see which you have to tilt the more to make the penny slide. The friction is greater in the case in which the tilting has to be more. You will then have compared roughly the friction between copper and wood, and copper and glass.

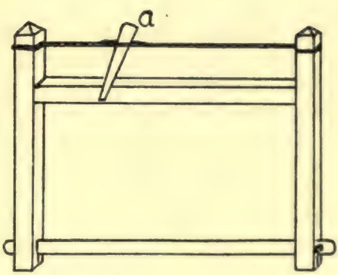
SOMETHING TO DO

1. **Flint and Steel.** Piece of old file ; flint ; charred rag ; and a tin box for storing them.
2. **Cock Call.** Tin can with resined string fixed through hole in bottom. Draw hand in jerks along the string.
3. **Bird Call.** Cork and bottle. Moisten cork with water, or methylated spirit, and rub on side of bottle.
4. **Razor Strop.** A piece of leather strap mounted as shown.
5. **Grub Saw.** Semicircular card for the saw with cork handle.
6. **Timber Saw.** Card blade ; wooden handles with saw cuts to take blade.
7. **Hand Saw.** Saw blade of card ; three card ovals fixed one over the other for handle. Cut away a portion of the middle one to make room for saw blade.

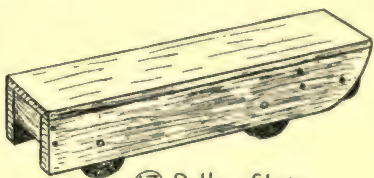


(11) Ice Yacht





(12) Stone Saw



(13) Roller Skate

8. **Marble Polisher's Block.** Block of wood with piece of thick flannel (or cloth) fixed as shown. Two handles pass through staples, and can be withdrawn for storage.

9. **Friction Tester.** Board with card tacked at end ; a tie clip, or wire paper fastener, with plumbline—cotton and boot button. Put a scale of inches along edge of the board. *Example :* Test friction between copper and glass and silver and glass. Sheet of glass with plumbline attached as shown. Put on it a penny, and tilt the glass till the coin slides. Measure height of tie clip above base. Note distance from the card to plumbline. Divide the first number by the second. Do the same using half-a-crown. The greater the fraction, the more the friction between metal and glass.

10. **Toboggan.** A post card marked as shown in plan ; shaded parts cut out ; front rolled over a pencil for curve. Cotton "reins" ; seat—a strip of card bent four times.

11. **Ice Yacht.** Two laths, cotton reel, bamboo flower sticks. Slides are cut from tin. The rudder should have one or two washers, or tin discs, or beads, between lath and back projection of rudder, as shown at *a*. Sail of muslin or paper. (Wheels may be used instead of runners.)

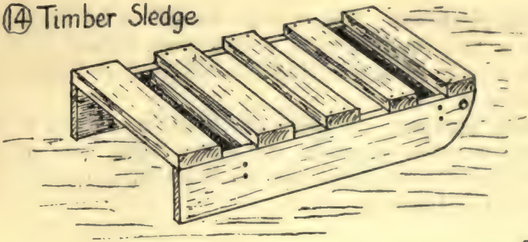
12. **Stone Saw.** Two uprights with saw cuts at bottom to take blade of crinoline steel ; crossbar ; string. Heat and soften the steel blade, punch holes one at each end for pegs to hold the blade. Fix for use as in sketch, using the peg *a* to twist the strings and tighten the frame.

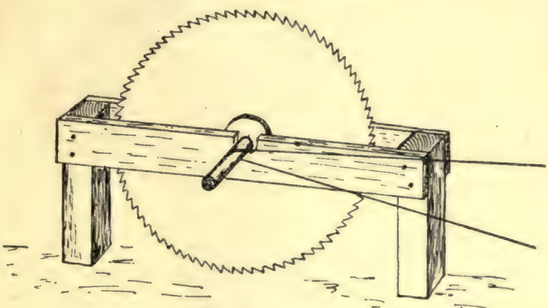
13. **Roller Skates.** Box of light wood strengthened by two cross pieces, as in sketch ; three cotton reels for rollers, the front one being a little higher than the others. Fix straps or tapes to sides. A block may be fixed to the top for the instep.

14. **Timber Sledge.** Construct from thin wood. Put a hole at the front of each runner for rope traces, and strengthen by two cross pieces as shown.

15. **Circular Saw.** Fit up as for grindstone. Make a saw of card or tin. At each side where axle passes through the disc, put a thin slab of cork for support. When mounted, cut a table from card, and make a slot as shown, and put on top of frame. Cotton runs to driving wheel.

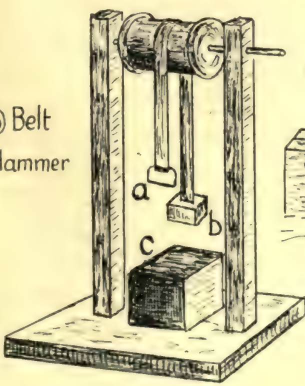
(14) Timber Sledge





(15) Circular Saw

(16) Belt Hammer



(17) Boot Scraper

16. **Belt Hammer.** Fix a wire handle *a* to tape carrying hammer *b*, and passing over a reel fixed firmly to the axle, which is slowly turned lifting *b*. When *a* is lifted, *b* drops on to anvil *c*.

17. **Boot Scraper.** A piece of hoop iron fixed firmly between two wooden supports, the latter being held in position in ground by three pegs—two in front at ends, and one at middle of the back.

CHAPTER X

Surface Tension

THE picture *Bubbles*, by Sir John Millais, Bart., P.R.A., is perhaps the most widely known picture in the British Isles. The expression on the little boy's face is one of intense interest and wonder at the beautiful colours he sees in the bubble, as it floats away.

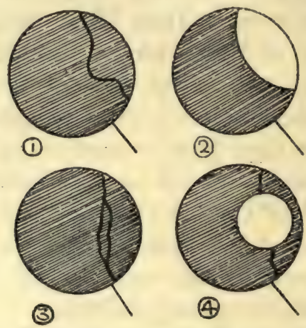
It is more than likely that you yourself have at some time or other blown bubbles, and watched them drift away and burst. Apart from noticing the wonderful rainbow colours, most people think no more about them after they have ceased to be. Yet some of the greatest scientists of our own and other days have devoted much of their time to studying the soap bubble, and wonderful things have been learned as a result of their work. Sir Isaac Newton was one of the many who spent days in studying soap bubbles.

You know that before the bubble is broken away from the pipe, it is not always shaped like a ball, but no sooner is it separated than it takes up the shape of a sphere. You can make the soap bubble alter its shape by blowing it as it passes by, but it is so elastic that it soon becomes a sphere again. In fact it behaves like a very thin india-rubber ball, and can actually be made to bounce like a ball! Put a little vinegar and soda in a large deep bowl. A heavy gas is made, which is there although it cannot be seen. Now drop a soap bubble into the bowl. It bounces as it falls on the layer of heavy gas, just like a rubber ball dropped on the floor. The skin of the bubble that contains the air is exceedingly thin, but highly elastic so that it can resist a certain amount of pressure.

9—(695A) 12 pp.

Soap Films. Suppose, instead of blowing bubbles, we try to learn something about the film containing the bubble. Take some carefully made wire circles about two inches across, with handles. Soak a cotton thread in soap solution, and tie it loosely across one of the frames. Dip the frame into a saucer of soap solution. A film which supports the thread is formed across the frame (1). Touch the film with a strip of blotting paper,

Bubble floating on gas

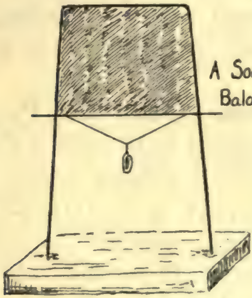


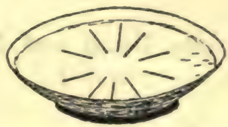
Experiments showing the Elasticity of a soap film.

and the film in that part gives way. The elastic film in the other part of the frame shrinks, and stretches the cotton into a smooth arc (2). Try again, but this time make a loop in the cotton (3). Touch with the blotting paper at the middle of the loop. The loop is drawn out into a perfect circle by the stretching force of the film, which must be pulling equally in all directions or we should not get a circle (4). So elastic is this film that we can make a balance with it.

Soap Film Balance. Construct a wire frame, as in the sketch, four or five inches wide. Place a piece of wire

across the frame, fastened at each side loosely so that it can slide up or down. To this wire attach a tie clip by means of cotton, as in the sketch. Dip the upper part of the frame and the loose wire placed across it into a saucer of soap solution. Stand the frame upright. The wire slides down a little, stretching the film, and by attaching light things to the tie clip, the power of the film can be tested. Many interesting things about soap





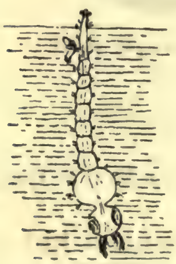
films can be learned from *Soap Bubbles, and How to Make Them* (S.P.C.K.).

Pond Skaters. The surface of water behaves just as the elastic film making the soap bubble. Who has not seen the "pond skater" skimming along on the surface of the water in ponds and ditches? He has not the slightest fear of drowning. The surface film is able to hold him up quite easily. "Whirligig beetles and springtails, too, are held up by the toughness and elasticity of the water film. Life among springtails is not all jump and fight. Hygiene also plays a part; in fact, when time allows, old and young, children and babies, wash their faces and comb their backs. The little animal licking one of its front legs, as it is quite unable to break the

water film, carefully washes its face like some diminutive cat."[1]

Float a few match sticks arranged like the spokes of a wheel, on quite clean water. Touch the water at the centre of the wheel with a piece of soap. The sticks run away! The reason for this is that where the soap touched the water surface it lessened the strength of the film. At other parts of the surface the film was not weakened, so the elastic force pulled the surface layer away from the weakened spot and the sticks went with it. Among the many things that will weaken the strength of the water surface is oil.

Panama Canal and Mosquitoes. When the Panama Canal was planned, no one dreamed that such a simple thing as surface tension would play so large a part in its completion. During the first attempt to cut the isthmus many thousands of men died of malarial fever. Finally the work was abandoned and machinery, to the value of many hundred thousand pounds, was left to rot. In the meantime, clever doctors had been studying the causes of tropical fevers, and had learned that these fevers were due to a certain kind of mosquito or gnat. Until it was possible to destroy this mosquito, the fever would be difficult to overcome. Then the entomologist—the man who makes a special study of insects—came to the help of the doctors. It was stated that the mosquito passes its early life in ponds and stagnant pools of water, floating near the surface with its head below the water,



Mosquito Larva

[1] *Pond Life.* Ash.

and its tail penetrating the surface film. It is held up by the strength of the water film. Then came the physicist—the man who understands all about the things of which you have been reading in this book—and added his knowledge to that of the doctor and the entomologist. He said: "Reduce the surface strength of the water and you will drown the young mosquitoes by the million." His advice was taken. The marshes were drained to lessen the water surface and paraffin oil was poured on the water of the marshes and the mosquito plague abated. The work on the Panama Canal was taken up again and completed—a truly wonderful triumph for science. There is now a better way of destroying mosquitoes, as we shall see later.

Oil on Troubled Waters. Have you ever heard the expression "Pouring oil on the troubled waters"? Some time ago a tiny timber schooner was making a voyage from Nova Scotia across the Atlantic, with a crew of five only. Unfortunately she was caught in a gale, her masts snapped off, everything was swept from her decks, and she was leaking badly from the blows she received from the wreckage of her masts floating alongside. The men were lashed to the pumps and worked all night to keep her afloat. In the morning a steamer came near, and the schooner's captain tried to swim off to the steamer with a lifeline, but had to be hauled back. Then an oil tank steamer came on the scene, and "poured oil on the troubled waters." The oil drifted round the schooner, calmed the waves, and the tank steamer came quite near the little schooner, and took off the men. During the Great War such scenes occurred on several occasions. The surface tension of the sea water is strong enough to allow the waters to pile up high before curling over and breaking. When oil is poured on the water

the surface strength is lowered and the containing skin gives way more easily in front of the advancing wave, so that the water does not pile up so high, and therefore, does not break. This plan of pouring oil on the waters is used to enable life boats to get near a wrecked ship and the rescue work is carried on in water much calmer than the waters round about.

Surface Tension and Globules. When a liquid wets a surface it spreads over it, as water spreads over glass. Mercury will not wet glass, that is it does not spread over it. A tiny drop of mercury on glass is like a little ball as it rolls about. Water does not wet greasy paper but gathers itself up into little balls as the mercury does on glass. The surface tension or strain in its " skin " is great enough to overcome the force of gravity which of course tries to draw every particle of the drop downwards, and so flatten it out. It is this property of the " skin " that makes dew drops spherical.

Lead Shot. In the making of small lead shot, lead is melted and poured through a kind of sieve, at the top of a high tower. The drops become spherical and solid as they fall. A tank of water is placed to catch them and prevent them from being damaged by the fall.

There is a legend that a man sold himself to the devil. Afterwards he was sorry and asked to be set free. The devil told him he should be free if he performed three tasks: He must make a rope out of sand; he must boil water without fire; he must carry water in a sieve. The tasks look hopeless enough, yet you may be surprised to know that all three have been accomplished by science.

Carrying Water in a Sieve. Glass is made from sand, and glass wool can be made into a rope. Count Rumford long since boiled water by friction—and water *can* be carried in a sieve! Bend up the sides of a piece of wire

By courtesy of *The National Lifeboat Society*

OIL ON TROUBLED WATERS

gauze of not too open a mesh, and dip it into melted paraffin wax. Take it out, tap it to shake off any superfluous wax, and let it cool. When cold, water can be put into it by placing a piece of paper on the bottom and letting the water fall very gently on the paper and spreading. The water does not wet the wax, and the surface tension of the water keeps it from breaking through the meshes. The skin seen from below bulges between the meshes but does not give way.

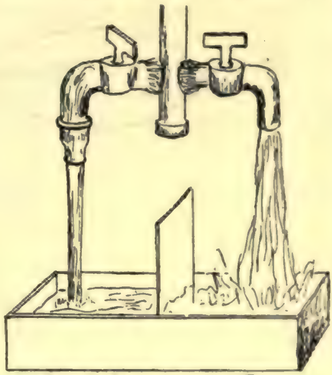
If you look carefully at your clothes you will find that the cloth threads cross each other in just the same way as the wires in the gauze. Yet a cloth cap will not hold water like the sieve ! But does not the idea occur to you that we ought to be able to make your cloth cap watertight, without blocking up the tiny holes, if we can only find something with which to treat the fibres and make them behave like the wires of the sieve ? It has been done. One of the earliest methods of doing this was by ironing beeswax into the fabric.

Shower Proof Fabrics. Of late years quite a number of cloths have been treated with chemicals which water will not wet, and so we have shower proof cloths. These keep out the wet but let air pass freely for ventilation purposes. You may, perhaps, see in a tailor's shop window a layer of the cloth used as an aquarium, with water, and gold fish swimming in it.

For ages we have used tents. These like our umbrellas are porous, yet the water does not pass through. The surface tension prevents it getting through the fabric unless the inside is touched. Then the surface of the water is broken and it comes through. Those of you who have been camping with the scouts know how careful the inmates of a tent must be on a wet night not to touch the inside of the canvas—or the results are disastrous.

These small openings between the fibres that make the fabric are like little capillary tubes—in fact capillarity and surface tension are very closely connected.

Antisplash Tap. A very clever and useful invention was introduced a few years ago. Perhaps you have seen an *antisplash* tap. This depends for its smooth working on surface tension. The water forced through a piece of wire gauze is broken up into a number of fine threads of water, each enclosed in its own *skin*. These run together, it is true, but the issuing water no longer comes out of the tap in a turbulent state, as each thread of water travels in a direction parallel to that of the others. In the usual case there is confusion within the water jet and that leads to splashing.



Antisplash and Common Tap

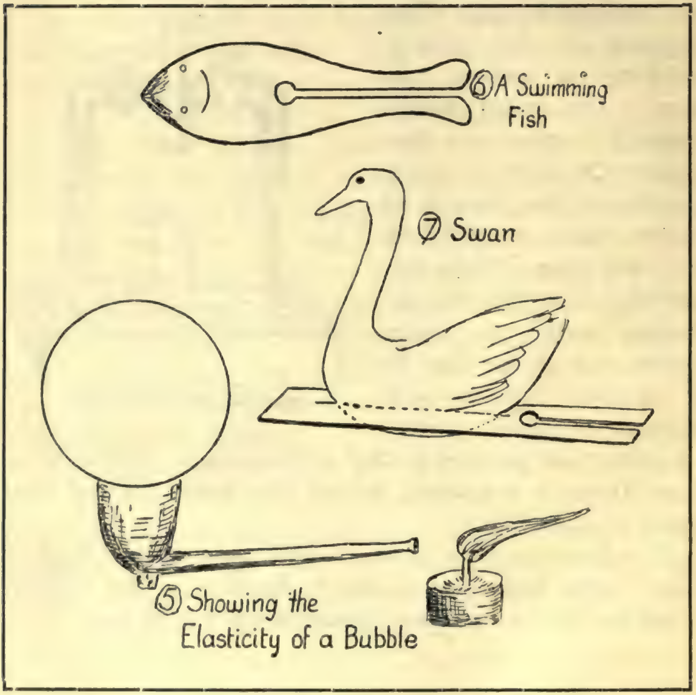
In a laboratory we often use this water *skin* to help us pour liquid from one vessel to another. This is done when we let the liquid run gently down a glass rod.

SOMETHING TO DO

1. Make a soap solution, and blow bubbles.
2. **Strength and Elastic Property of Film.** Make wire loops about 2 in. diameter from rusty wire, and carry out the experiments on page 122.
3. **Match Sticks and Surface Tension.** Break off the upper ends of several matches, arrange remainders radially in a

saucer of water, but with space at centre. Touch the space with a piece of soap, and note the movement of the sticks.

4. **Float a Needle on Water.** Put a small piece of blotting or cigarette paper carrying the needle on water. The paper



becomes wet and sinks, leaving the needle supported by the surface film.

5. **To Show Elasticity of Soap Bubble.** Blow a bubble, and hold as in the diagram. As it contracts, the air is forced out through the pipe and blows the candle flame away from it.

6. **Swimming Fish.** Cut a fish as shown and float on water.

Put a drop of oil in circular hole, and note the movements of the fish.

7. **Swan and Camphor.** Cut a paper swan, and mount in slit in slip of cartridge paper which has a cut as in fish. Put a small piece of camphor in the circular hole, and note the effect.

8. **Surface Tension Balance.** Wooden base; wire frame, about 6 in. apart at lower and 4½ in. at upper end, and 1 ft. high. Movable wire to carry cotton and wire paper fastener. Dip upper part in saucer of soap solution. Let movable wire slip down till at rest, and then test whether the film will carry a sixpence held in paper clip. (For sketch, see p. 123.)

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